NABERS UK

Example Simulation Report

Version 1.0 – September 2021

NABERS UK is owned and overseen by the New South Wales Government, Australia and managed by the Building Research Establishment (BRE) as the UK Scheme Administrator. Published September 2021.

Published by
Building Research Establishment (BRE)

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September 2021

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Acknowledgements

This report was adapted from a project Simulation Report prepared for Lendlease Europe by Lendlease Integrated Solutions. The project was selected as it provides a best practice example of a Simulation Report that can be used as a reference point by developers and their project teams who have signed Design for Performance Agreements. The generosity of Lendlease Europe and its project team in providing the report and answering queries is gratefully acknowledged. The adaptation of the report was funded by the Better Building Partnership and undertaken by Dr Paul Bannister of DeltaQ Consulting Services and Dr Robert Cohen of Verco Advisory Services.

1 Introduction

1.1 Summary

Design for Performance (DfP) provides a framework by which projects can commit during pre-construction to achieve a NABERS Energy for Offices target rating in post-construction performance. Projects subject to a Design for Performance Agreement process (See Figure 1) are required to undertake Advanced Simulation Modelling in line with the Guide to Design for Performance and produce a Simulation Report that forms a part of the Independent Design Review.

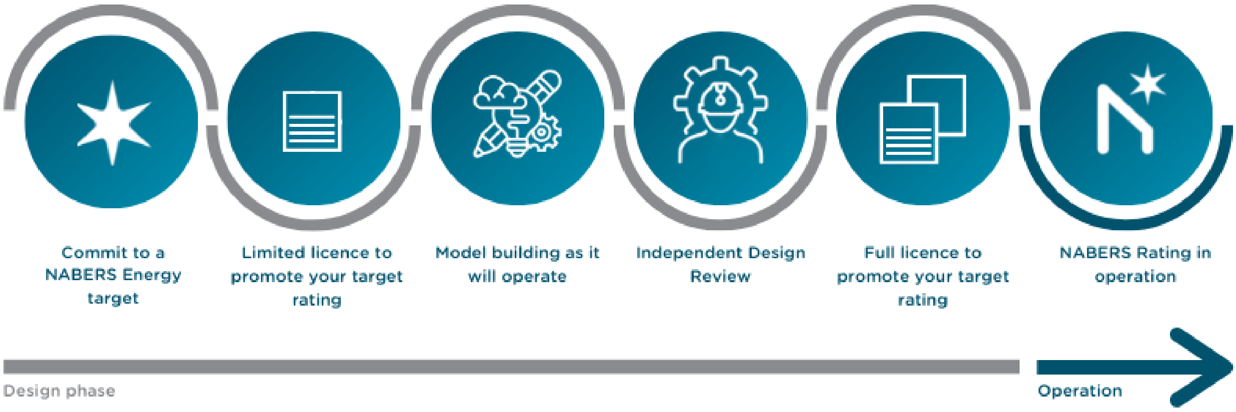


Figure 1 Design for Performance Process

1.2 About This Report

This report is an example simulation report that demonstrates the key features of a simulation report compliant with the requirements of a Design for Performance Agreement. A Simulation Report should provide a realistic estimate of the operational energy performance of the project. As a part of the Independent Design Review process, it is a requirement to provide a Simulation Report to the selected Independent Design Reviewer for evaluation. This example simulation report was produced during RIBA stage 4 design when there is more documentation and design detail for the Simulator than would be the case for simulation work earlier in the design process. More information on the sections that a simulation report should contain, and its format can be found in the Guide to Design for Performance.

This report is a heavily edited version of a real simulation report for a real project, which has been anonymised. We have also made some changes to the technical content and results so even if the original project is identified, this report is not representative of the results obtained.

Notes and commentary are provided in grey textboxes such as this.

1.3 Audience

This Example Simulation Report is intended to provide assistance for all parties involved in the Design for Performance process, in particular the person(s) conducting the Advanced Simulation Modelling, referred to as the Simulator, in terms of understanding the level of detail and depth of reporting required. It is also intended for the Design for Performance Agreement Applicant and the Independent Design Reviewer in terms of what to expect from a Simulation Report.

1.4 How To Use This Report

Simulators should use this report as a guide to the content and depth of reporting required for use in Design for Performance agreement simulations.

Independent Design Reviewers should use this report as benchmark of expectation for what such a report should include.

Developers should use this report as a reference for what should be expected of a competent simulation report.

1.5 Disclaimer

No party associated in any way with the production or distribution of this report accepts any liability for any loss, financial or otherwise, caused directly or indirectly in association with the use of this report.

It is noted that while the technical content of this report is of high quality, there are technical decisions and assumptions made that are open to debate and discussion, as with any such report. The technical content, design solutions and assumptions of this report do not have any endorsement by their presence in this example report and of course represent items that may be unique to the original project. Content is included solely to provide readers with a good example of the depth of thinking, simulation detail and reporting needed for a simulation to provide maximum value to the Design for Performance process.

2 Example Simulation Report

Example Tower, 1 Test St, London W1

2.1 Executive Summary

The Example Tower, 1 Test St is a high-rise 33,000m2 Net Internal Area (NIA) air-conditioned office building with retail on its ground floor. It is located in London W1. The project has registered a Design for Performance Agreement with NABERS UK and is seeking to achieve a high level of energy efficiency as measured by a NABERS Energy rating.

Based on the results of this report, base case scenario indicates that the building has the potential to achieve 4.77 stars, which represents 8.7% lower kWhe than 4.5 stars and 23.9% lower kWhe than 4 stars. Off axis scenarios indicate a range of risks that reduce the potential rating to 4.21 stars in a combined risk scenario. As we consider that a minimum 20% margin should be allowed between the simulated rating and the achievable target, we recommend that the simulation is taken as an indication that the building can achieve 4 stars. While 4.5 stars is theoretically possible, we would consider that the 8.7% margin is too narrow to provide any confidence of achievement in practice.

Computer simulation provides an estimate of performance. This estimate is based on simplifications that do not and cannot fully represent all the intricacies of performance once built. Simulation results only represent an interpretation of the potential performance. Beyond these modelling challenges and limitations, many other factors will impact a NABERS Energy rating in operation such as the quality and workmanship with construction works, the nature of tenants occupying the building, the quality of the owner's operation and maintenance regime and weather. As a result, no guarantee or warrantee of performance in practice can be based on simulation results alone.

2.2 Introduction

This report has been prepared by [Consultant] to provide an estimate of the potential NABERS Energy performance of the proposed [Example Tower] commercial office building located at [1 Test St, London W1].

Building simulation and energy estimation has been carried out to communicate the estimated NABERS Energy rating of the proposed RIBA Stage 4 design. Energy simulation and analysis has been carried out in line with the Guide to Design for Performance (DfP) v1.0.

The report is structured as follows:

- Section 2.3 – Basis of Energy Analysis: Summarises the nature of simulation and its limitations as well as the software and methods used in arriving at the predicted performance.
- Section 2.4 – Results and Discussion: A discussion on the simulation results to provide greater insight into the nature of mechanical system energy use and performance.
- Section 2.5 – Sensitivity & Off-Axis Analysis – Quantifies the potential impact of a range of risks to performance and sensitivity to simulation assumptions.

- Section 2.6 – Energy Coverage and Metering Arrangements – a summary of observations on metering requirements to enable a NABERS rating and some of the risks.
- Appendix A – Building Assumptions provides a detailed summary of the building related assumptions on which the predicted performance is based.

2.3 Basis of Energy Analysis

Note: The report starts by setting put some basic information on the simulation package and the limitations of how the building was represented. Many projects might also choose to include some aspects of the information in Appendix A at this point, which would also be valid. However, in the context that most readers of this report will be looking to get to the results sooner rather than after pages of descriptive text, the relegation of most of the basic material to an appendix is a sensible approach.

2.3.1 Nature of Simulation

Computer building energy simulation provides an estimate of building energy performance. This estimate is based on a simplified and idealised version of the building that does not and cannot fully represent all the intricacies of the building once built and operated. As a result, simulation results only represent an interpretation of the potential performance of the building.

Care has been taken in interpreting the design intent of the base building and its systems and developing a representation of the building in an energy model / simulation. However, the performance in operation will vary from the assumptions underlying the energy model. These base building assumptions have been clearly outlined in Appendix A of this report.

2.3.2 Testing and Quality Assurance

IES's Virtual Environment (VE, 2019), has been utilised to assess the base building air conditioning systems including heating and cooling coil loads, air handlers, fan coil units, and heat recovery devices. Other landlord energy loads including pumping have been estimated using robust spreadsheet methods. The IES ApacheSim engine has undergone quality assurance tests using BESTEST / ASHRAE 140 and has compared favourably to the reference programs.

We also note that software that has undergone validation does not guarantee a reasonable modelling outcome. The user's interpretation of inputs and recognition of the limitations of a package are more significant and important variables.

2.3.3 Modelling Limitations

The approach to the analysis is described below along with how some of the key limitations have been overcome.

2.3.3.1 Approach

- All office base building, lobby, and basement air conditioning systems (air handling, chilled water etc.) are simulated within IES VE using Apsim and ApHVAC.
- Heating hot water and chilled water pumps have been modelled in a spreadsheet where full control over pump inputs, high flow low DT, and reticulation losses can be represented. This approach also allows IES VE generated coil loads to be coupled with coil loads

developed outside of the IES environment such as switch room or lift motor room cooling and the domestic hot water load on the LTHW circuit.

- Miscellaneous mechanical fans and equipment are estimated using spreadsheets from design duty information, making representative adjustments and efficiency assumptions, and then estimating full load equivalent run hours based on likely control philosophies.
- The energy use of other non-mechanical loads are estimated by spreadsheet calculations or by benchmarking to other projects. For example, house lighting is estimated from totalling circuit watts by area and control groups from lighting layouts and then estimating full load equivalent run hours based on likely control philosophies.
- Sufficient design information was available to avoid having to use benchmarks from other projects. However, there are several smaller end-uses that have had to be estimated using engineering judgement, e.g. greywater system and the closed cavity façade compressed air system. The assumptions we have made in these cases are outlined in Appendix A.
- We have followed the modelling requirements outlined in the Guide to Design for Performance including after-hours air conditioning requests on Saturdays. It is assumed that Level 17 (which represents ~5% of the building's net internal area) will be in operation between 9am – 12pm on Saturdays.
- Where we have not used the Guide to Design for Performance default assumptions, we have generally noted that in the assumptions and provided a reason why we have departed from the defaults.

2.3.3.2 Simplifications and Limitations

Note: This listing of simplifications and limitations not only helps the reader understand the limitations of the simulation, but it also helps demonstrate the depth of knowledge of the simulator and provides a space for a justification of choices made. This is greatly preferable to leaving the reviewer(s) (and client) to try to unearth these issues by reading between the lines.

The following simplifications and limitations in the estimate are summarised below. Where possible, slightly conservative assumptions have been made to address these limitations. We have also outlined any material departures from the Guide to Design for Performance modelling requirements. Appendix A provides additional detail where appropriate.

- **Basement** – the basement has not been modelled in entirety. The basement contains plant areas, cycle store, and end of trip amenities. The Part L insulation line wraps the basement in entirety and provides insulation between the unconditioned basement space and conditioned space above such as the lobby and reception area. The basement also receives tempered outdoor air and in the case of the end of trip facilities is heated to an 18°C minimum. For these reasons and to focus the modelling effort where it counts, we have represented only the end of trip facilities in the Apsim model as they are the space that sits below the conditioned office lobby and reception area. Outside of that area, the ground floor constructions are assumed to be adiabatic (noting they are insulated below) as they sit below unconditioned back of house space and retail areas. The basement AHU is modelled in ApHVAC as a 100% outdoor air system with the air short circuiting to the relief side of the heat recovery device. This may overstate the heat recovery but at times it will also be understating it due to internal loads.
- **Retail** – we have not modelled the ground level or Level 1 retail areas. The intent is to isolate these areas and exclude them from the NABERS rated energy. The neighbouring

wall and ceiling constructions to the office areas are modelled as adiabatic. By not including the retail CHW and HHW loads, the fixed thermal losses and pull down / pull up loads at start-up are 100% allocated to office uses when in practice they would potentially share some of those losses and thus be deducted from the Rated Energy. We believe this assumption is conservative provided the retail trades for hours similar to the office building. If the retail trades late at night and on weekends, then our assumption is optimistic as added losses would be shared with office loads.

- **Infiltration** – Infiltration has been modelled as a fixed value on a schedule rather than dynamic with wind speed. We believe this method is slightly conservative over the course of a year. Façade air tightness is specified at 5 m^3/hr / m^2 @ 50 Pa which using CIBSE Guide A Table 4.16 suggests 0.2 air-changes per hour (ACH) could be assumed where contractual processes exist to achieve that level of air tightness for the total building. We have assumed a time and area weighted average infiltration of 0.21 ACH and have run an off-axis scenario at a higher infiltration rate.
- **Internal Loads** – while the Guide suggests a range of five different equipment loads be used, we have assumed equal area splits of a high and low load scenario. In these two load templates we vary not just the equipment load but also the occupant density and lighting load as the highest equipment load areas in modern offices will typically be coincident with high occupancy and low loads vice versa (refer section A.5.4). In our experience this assumption is justified to simplify model validation. Furthermore, as fan coil units can trim cool and heat at a zone level without generating system recool or reheat, any added load diversity is highly unlikely to change energy use materially provided the high and low internal load assumptions bound the range of potential loads.
- **Office Partitioning** – generally more diverse loads will be serviced at a higher energy use than homogenous loads. Beyond the high and low internal load scenarios and to be slightly conservative, we have modelled a plasterboard wall between all zones. While not insulated, these walls will slow and contain heat in one zone for a longer period of time than if an air partition were used. Further, the wall isolates solar gains to the perimeter zones thus promoting active cooling more frequently and at a more intense level than if the sun were allowed to absorb into a greater surface area of thermal mass. An open office plan simulation will be lower energy use with all else equal.
- **External Shading** – The floorplate articulation and existing buildings are modelled to account for site shading and building self-shading. This is important as allowing winter sun penetration where it does not occur would lead to an optimistic energy model. There are some façade types that have expressed mullions and shallow fins that we have not modelled, which will result in a minor underestimate of solar heat gains (which may have either positive or negative effects depending on the zone heat balance). We have modelled the impact of the expressed mullions and fins on the overall system U-Values (added thermal bridging).
- **Plenums** – plenums are not modelled so recirculating air is from the conditioned space into the fan coil unit not via a plenum zone. This is felt to be an appropriate assumption as the façade system has virtually no spandrel between typical floors. This assumption has the effect of insulating the concrete slab (thermal mass) from the conditioned space more than if a plenum was modelled. On average having the concrete slab in greater thermal contact (if plenums were modelled) would lower cooling energy use and we believe would also lower heating loads for many conditions due to the added storage effect. For this reason,

we believe excluding plenums is slightly conservative while also managing simulation run times for a whole building model.

- **Air Handling Zoning** – to manage model complexity and simplify the risk and sensitivity analysis process, we have modelled the north and south dedicated outdoor air handling units as a combined unit. As the systems are DOAS only, there is no reheat or recool that would occur in a four AHU arrangement that wouldn't be captured in the two AHU arrangement. The high and low-rise zones have identical operational profiles so there are no biases that are introduced with this modelling simplification.
- **Optimal Start** – the fan coil units and dedicated outdoor air handling units start at 7am and aim to meet the business hour space conditions immediately. The DOAS units are in full outdoor air mode during this time noting heat recovery is present.
- **Night Purge** – no night purge has been modelled which, if set-up correctly (to minimise fan energy use), may provide a net energy reduction by removing daytime / weekend heat build-up from the thermal mass.
- **Pumps** - the chilled water and heating hot water pumps are modelled in a spreadsheet using techniques that are more advanced than the simple turndown curves IES ApHVAC provides. Modelling in spreadsheets also allows us to group loads from non IES Apsim loads such as domestic hot water, tenant supplementary cooling, switch room cooling etc while also modelling thermal reticulation losses in one place. This method has the advantage of modelling high flow low ΔT effects more transparently. Overall, in our experience this is a more robust method of modelling hydronic plant equipment.

2.4 Results & Discussion

Note: As with the simplifications and limitations section 2.3.3.2, this section is useful to the reader in that it summarises all the things that the simulator has considered to be important and has hopefully represented in their simulation. While it is no substitute for due diligence in reviewing design documentation by the reviewer, it is of great help to all readers.

2.4.1 Greenhouse Performance Features

The [Example Tower] development is committed to reducing its carbon emissions by more than 30% compared to the minimum performance requirements as outlined within the Building Regulations 2013 Approved Document L2A (AD L2A). In the pursuit of such high levels of energy efficiency, the design team have already incorporated the following base building features:

- **High Performance Facade** – The glazing systems proposed to the office areas varies up the building and around each facade, however the proposed façade types maintain a high-performance outcome throughout. A mixture of double-glazed façades systems achieving G-values between 0.28 and 0.36 and total system U-Values of between 1.40 to 1.60 W/m^{2}°K (glass & frame). The façade systems incorporate thermal breaks and argon fill to improve the overall insulation value.
- **Insulation levels** – Insulation levels to walls, roofs, pipework and ductwork is in line with the Part L of the Building Regulations.

- **Closed Cavity Façade –** Façade types 3 & 4 utilise a closed cavity façade system with interstitial blinds to control direct solar radiation. The closed cavity façade achieves a G-value of 0.49 without blinds, and a combined G-value of 0.13 with blinds. System U-Value is less than or equal to 1.1 $W/m^{2}{}^{\circ}K$ as an argon filled lowE DGU is used internally.
- **Air Handling** – Air handling units have been designed to minimise system pressures and maximise fan wire to air efficiencies. Outdoor air is supplied to the zones at a maximum rate of 1.7 $L/s/m^2$ and adjusted to maintain a maximum CO_2 level of 800ppm (equates to ≈12.9 L/s/person assuming 400ppm ambient). Economy and night purge cycles increase outdoor air rates above minimum when conditions are favourable.
- **Heat Recovery –** all major air handling systems incorporate heat recovery wheels. These are total heat recovery based with a minimum effectiveness of 73% specified.
- **Pumping –** Pumping systems are generally variable flow and variable pressure to minimise energy use.
- **Ground floor lobby** – The ground floor lobby will be conditioned via a constant volume AHU, with trench heaters to maintain a minimum 18°C.
- **Common Light & Power** – High efficiency LED lighting will be used throughout with demand based addressable controls as appropriate (daylight switched/dimmed, occupancy sensors etc.). For example, lift lobby, toilets and stair areas will be switched on motion sensors. Stair areas will maintain a minimum illumination for safety purposes.
- **Renewable Energy Systems** – A 18 kWp photovoltaic (PV) array has been included on the rooftop of the development.
- **Chiller Water** – Chilled water is delivered to the building by Engie, a district cooling network via plate heat exchangers in the basement.
- **Heating Plant** – Heating hot water is delivered to the building by Engie, a district heating network via plate heat exchangers in the basement. Hydronic heating is also provided to select areas via hot water radiators and trench heaters.
- **Supplementary Systems –** tenant supplementary cooling (tenant chilled water) is provided as an allowance of the overall chilled water provision. Chilled water is provided to tenants without a clear demarcation between space conditioning and supplementary cooling.

2.4.2 Assumed Operating Parameters

Note: The tabular format used in this section of the report allows a great deal of information to be summarised in a small space.

The key operating parameters assumed for the purposes of estimating the potential NABERS Energy rating are detailed in the table below. The operational assumptions used in the energy analysis assume load diversification. While the extent of load diversification is uncertain and will impact the predicted rating, it is highly unlikely that tenants will utilise the full mechanical design allowance for all operating hours.

Table 1 Office Tenant Usage Assumptions

Assumptions	Mechanical Design Criteria	Operational Assumption for Analysis (High / Low Load)
Business Hours Average Occupant Density (m^2 NIA/p)	8	8 / 12 @ 70%
Business Hours Average Light Heat Loading (W/m^2 NIA)	10	7 / 4 @ 100%
Business Hours Average Equipment Heat Loading (W/m^2 NIA)	15	11.3 / 6.7 @ 100%
Established Building Hours (hrs/week)	NA	50
After Hours Air-Conditioning requests (hrs/week area weighted)	NA	Saturday 9am-12pm across 5% of floor area = +0.15 hrs/week
Rated Hours (hrs/week)	NA	50.15
Occupied and in use Area	NA	100% NLA
Space Temperature Set points (°C)	CLG 24 ± 2 HTG 20 ± 2	Proportional Bands CLG 23 - 24 HTG 20 - 21
Tenant Supplementary Cooling (Wr/m^2 NLA)	10	2.5 but with thermal meter deduction
Lift Energy Use (kWh/m^2 NLA pa)	NA	4 + Cooling and FCU
Weather	NA	London CIBSE TRY

The default schedules in Section 8 of the NABERS UK *Guide to Design for Performance* have been utilised when scheduling HVAC operation and internal heat gains. The schedules are not repeated here as they are available in the guide. The schedules align with the following operational profile:

- 8am-6pm Monday to Friday normal established building hours (50 hours/week).
- The air handling plant starts at 7am on all weekdays to pre-condition the space.
- After hours operation is assumed for Level 17 (equivalent to approximately 5% of the building's net internal area), for 9am-12pm Saturday.

As per the NABERS UK *Guide to Design for Performance*, the London CIBSE TRY file has been used and is considered representative of the climate local to the site.

2.4.3 Predicted Performance

This section summarises the predicted base building performance in detail to understand the relative of impact of different end uses and how variable and weather sensitive systems are predicted to perform over the course of a year.

2.4.3.1 Predicted Energy Use

Note: The energy summary table has the key features needed – it lists energy by end-use and by source and provides a total. Note that units are clearly stated.

The table below summarises energy use by key end use or building components. NABERS uses an electricity equivalent weighting factor of 0.4 (COP of 2.5) for district cooling and 0.9 for district heating to convert thermal energy supplied into an electrical equivalent, hence the multiple columns presented below.

Table 2 Base Case Model Predicted Energy Use

	Electricity (MWh)	District Cooling (MWht)	District Heating (MWht)
Space heating	5.7		1042.4
Space cooling	12.8	584.0	
HVAC fans	331.2		
Tenant supplementary cooling	5.5	248.4	
MEW and Switchroom cooling	31.4	75.4	
Misc house AC	6.5	14.5	8.8
Misc house fans	43.8		
House lighting	195.4		
External lighting	2.3		
Closed cavity façade compressed Air	15.2		
Other House power	39.0		
DHW	44.1		212.8
Hydraulic pumping	17.2		
Greywater	7.2		
Vertical transport	134.2	152.9	
Electrical reticulation losses	17.8		
On-site generation	-11.9		
Net Base Building Demand	897.4	1075.2	1264.0

The figures represented in the end use table are simulated with no modelling margin.

The table below clarifies the specific systems and end uses included in the table above and section 2.5 Sensitivity and Off-Axis Analysis. Note retail and tenant energy use is excluded in entirety.

Note: The clear statement of coverage in the table below assists readers greatly in understanding what has and has not been included in the simulation. Lack of clarity on this point is a common flaw in many simulation reports.

Table 3 Equipment included in Tabulated Values

	Electricity	District Cooling	District Heating
Space Heating	• Proportionate LTHWP pumps including secondary within office floors • L22 overhead door frost protection	• N/A	• All LTHW coils in AHUs, FCUs • LTHW trench heaters and panel radiators in BoH areas • Thermal reticulation losses (proportionate)
Space Cooling	• Proportionate CHW pumps including secondary within office floors	• All CHW coils in AHUs, FCUs with exception of FCUs list under House Miscellaneous • Thermal reticulation losses (proportionate)	• N/A
HVAC Fans	• All AHUs (supply and relief / return where present) and all main office area FCUs including the FCUs to typical floor amenities	• N/A	• N/A
Tenant Supplementary Cooling	• 100% CHW pumps including secondary within office floors	• All supplementary cooling is assumed to be base building energy as tenant fit out CHW provision is intended for space conditioning and not for computer room cooling which would be eligible for	• N/A

		metering an adjustment to benchmark. • Thermal reticulation losses (proportionate)	
MER & Switch room Cooling	• Main equipment room electricity use • Proportionate CHW pumps	• Thermal loads to cool switch room and main equipment room • Thermal reticulation losses (proportionate)	• N/A
House Miscellaneous Splits, FCUs, Door Heaters	• Fan energy use for all miscellaneous FCUs and CRAC units. • On floor office area and amenities FCUs are included in HVAC Fans	• Refer to appendix assumptions, but includes CHW cooling and LTHW heating for: • Reception - Breakout Area Adjacent to Desk • Reception - Desk • Security Room • Dock Managers Room • Active Lobby - Garden Stair • Active Lobby - Garden Stair • Facilities Management Office • Facilities Management Welfare • Thermal reticulation losses (proportionate)	
House Miscellaneous Fans	• Refer appendix but includes all house fans not modelled above	• N/A	• N/A
House Lighting	• All base building lighting internal to building	• N/A	• N/A
External Lighting	• External base building lighting	• N/A	• N/A
Closed Cavity Façade Compressed Air	• Air dryer (chiller) and compressor for CCF system	• N/A	• N/A
Other House Power	• Base Building backup generator oil sump heater • Trace heating • Miscellaneous allowance (cleaning	• N/A	• N/A

	equipment, fire systems etc)		
Hot Water System	• Proportionate primary LTHW pumping • Electric boost for HWS after hours losses	• N/A	• Typical floor basin amenities and basement End of Trip hot water service • Business hours thermal losses
Hydraulic Pumping	• Hot water service circulation pumps • Potable cold-water booster pumps • Cat 5 recycled water booster pumps	• N/A	• N/A
Greywater System	• Filtration and treatment system energy use	• N/A	• N/A
Vertical Transportation	• Lift drive energy use • Proportionate CHW pumping	• Lift motor room cooling • Thermal reticulation losses (proportionate)	• N/A
Electrical Reticulation Losses	• I2R losses in electrical reticulation system between utility meters and equipment modelled	• N/A	• N/A

2.4.3.2 Predicted NABERS Energy Rating

We have used the UK NABERS Simple Calculator and Reverse Calculator to estimate the achieved rating and the margin relative to the 4 and 4.5 star thresholds. Results are listed in the table below.

Diesel fuel oil is not included in the assessment below and would be limited to testing and thus minimal.

Note: The explicit listing of all inputs used – and outputs obtained – in obtaining the NABERS rating is critical so that the Independent Design Reviewer can reconstruct and check the rating calculation.

Table 4 NABERS Estimate Inputs

	Base Case
Postcode	W1
Rated Area (m^2 NIA in office use)	31,000
Rated Hours (hrs/week)	50.2
Modelled Electricity (MWhe)	897.6
Modelled District Cooling Thermal (MWht)	1,075.2
Modelled District Heating Thermal (MWht)	1,264.0
Modelled Tenant Server Room Thermal (MWht)	248.4
Total MWhe	2465
4.5 star threshold MWhe	2700
4 star threshold MWhe	3240
NABERS Energy Rating	4.5
Decimal Scale	4.77
Margin relative to 4.5 stars	**8.7%**
Margin relative to 4 stars	**23.9%**

Given these results and from the other off-axis scenarios (refer to Section 2.5) assessed we recommend the current design be interpreted as capable of achieving 4 Star NABERS Energy if substantially occupied and managed well through construction, commissioning, tuning and operation.

We also note several metering assumptions have been made to capture the on-floor tenant fan coil units and CHW & LTHW pumps (refer Section 2.6). Currently the Cat A electrical specification does not require sub-metering of the FCUs and on-floor pumps which would worsen the potential ratings above by an estimated 0.22 Stars due to the default energy allowances that would have to be used (-0.28 Stars if the FCUs are enabled to be variable speed). If this configuration persists, 4 Stars NABERS Energy becomes a riskier target rating.

Further optimisation and/or greater certainty on key assumptions would be required before 4.5 Star could be targeted. Key scenarios for building improvement have been tested and provided to the project team but have not been incorporated into the simulations for this report.

2.4.3.3 Nature of Predicted Operation and Energy Use

The following charts and discussion provide additional insight into the nature of mechanical system energy use which is dynamic with loads and weather. While it is recognised that the Base Case simulation is a theoretical peak that may never be reached, the patterns of equipment operation and energy use should still be believable and representative of the actual building. Reviewing this simulation in detail increases confidence in the results and that a well-behaved simulation has been created. This then provides a strong basis for relative comparisons and risk assessment.

This section of the report focuses on the air conditioning systems used for maintaining space conditions, as these are the systems where the greatest simulation risks normally lie and are thus the most critical to understand in detail.

Annual Energy Use

The chart below shows annual base building energy use by month and end uses for the mechanical end uses simulated in IES. These end uses are pre weighting and pre calculation of losses or pump energy use – they are the raw outputs from IES VE and thus represent thermal loads for cooling and heating and fan electricity use.

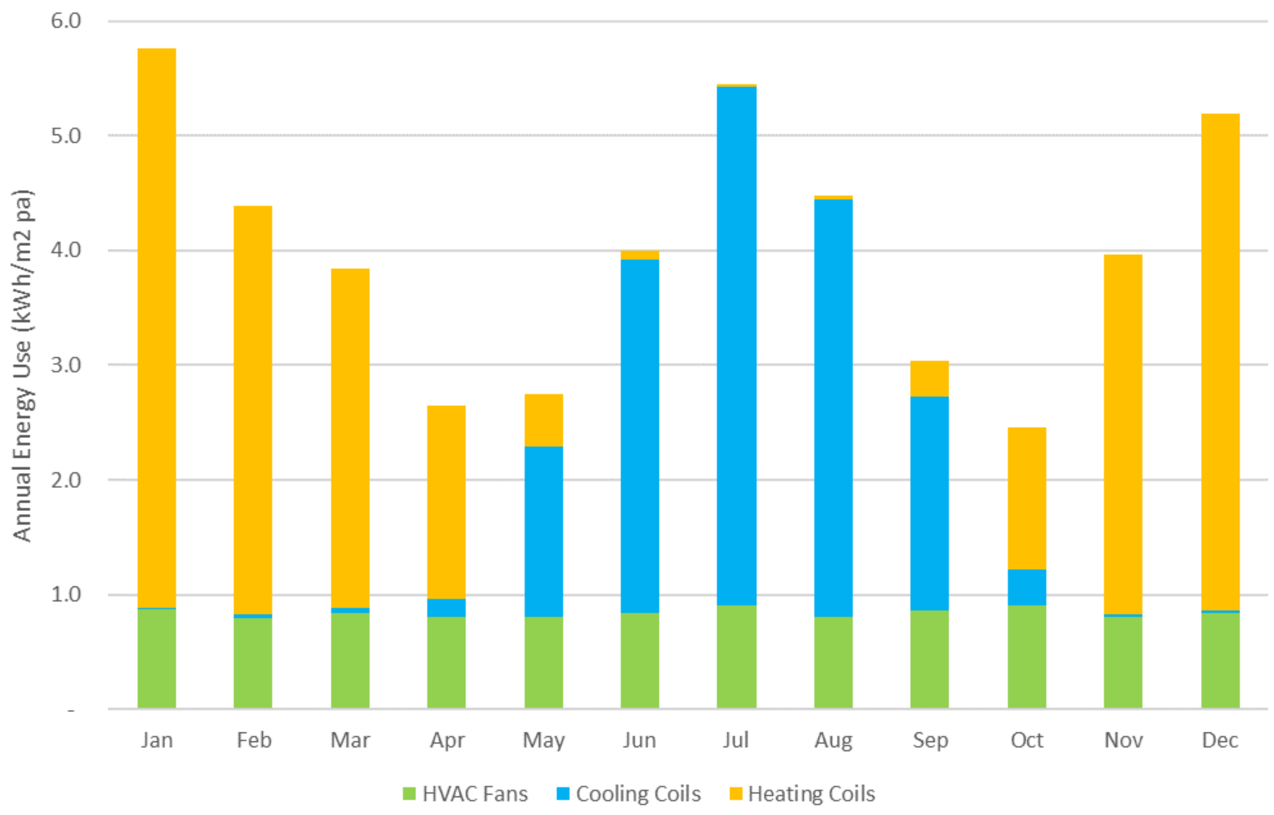


Figure 2 Annual Energy Use by End Use

Some key observations from this chart include:

- Fan energy (AHU ventilation fans and on-floor FCUs) is constant throughout the year due to FCUs being simulated as constant volume. Demand controlled ventilation is not weather sensitive and therefore does not vary fan energy use with seasons.
- Economy cycle controls are slightly imperfect in winter which may be explained by fan heat gain. This should be reviewed to account for fan / duct heat gain biases when developing control strategies
- Heating is significant, particularly once thermal losses and NABERS weighting factors are applied

A detailed breakdown of end uses is provided in Table 5 below.

Table 5 Detailed Energy End Use Breakdown

Source	End Use	Energy Type	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Hourly Loop Calcs	Heating - Office FCUs	LTHW Thermal Secondary	kWht	147862	112006	94506	57110	20093	4177	1096	1560	16383	53576	103521	133112	745003
Hourly Loop Calcs	Heating Other BB	LTHW Thermal Secondary	kWht	56232	42202	38412	30541	20305	16672	16408	15598	17786	22294	34408	49063	359921
Hourly Loop Calcs	Heating - Utility Meter	LTHW Thermal Primary	kWht	220372	167924	146348	101105	54152	34781	27996	27546	47550	90203	149796	196255	1264029
Hourly Loop Calcs	Cooling - Tenant Supplementary	CHW Thermal Secondary	kWhr	22264	19882	21557	23120	20581	18568	19953	18353	20343	24071	19830	22746	251267
Hourly Loop Calcs	Cooling - Office FCUs	CHW Thermal Secondary	kWhr	255	1508	1896	6810	55698	107216	150963	126345	69292	13440	952	877	535253
Hourly Loop Calcs	Cooling - Other BB	CHW Thermal Secondary	kWhr	17988	15832	16884	19091	17985	21715	28075	20971	19207	19111	15947	18097	230905
Hourly Loop Calcs	Cooling - Utility Meter	CHW Thermal Primary	kWhr	44631	41490	45668	55471	99192	151541	203149	169412	113730	63583	40937	46434	1075239
Hourly Loop Calcs	LTHW Pumps	Electric	kWhe	1550	1164	1026	692	370	230	197	183	299	466	767	1132	8077
Hourly Loop Calcs	CHW Pumps	Electric	kWhe	678	672	842	1173	2133	3500	4915	4145	2409	1384	837	804	23492
IES Simulation	AHUs	Electric	kWhe	16609	15068	16114	15429	15611	15916	17092	15596	16428	17109	15433	16110	192515
IES Simulation	Office FCUs	Electric	kWhe	12377	11225	11776	11181	11188	11738	12853	11188	12295	12853	11201	11796	141671
Spreadsheet	Misc Mech	Electric	kWhe	4316	4316	4316	4316	4316	4316	4316	4316	4316	4316	4316	4316	51796
Spreadsheet	House Lighting	Electric	kWhe	16943	16943	16943	16943	16943	16943	16943	16943	16943	16943	16943	16943	203321
Spreadsheet	DHW - After Hours	Electric	kWhe	3689	3689	3689	3689	3689	3689	3689	3689	3689	3689	3689	3689	44268
Spreadsheet	DHW - Business Hours	LTHW Thermal Secondary	kWht	13053	13053	13053	13053	13053	13053	13053	13053	13053	13053	13053	13053	156641
Spreadsheet	Other House Power	Electric	kWhe	7810	7810	7810	7810	7810	7810	7810	7810	7810	7810	7810	7810	93720
Spreadsheet	Hydraulic Pumping	Electric	kWhe	1476	1476	1476	1476	1476	1476	1476	1476	1476	1476	1476	1476	17716
Spreadsheet	Lifts	Electric	kWhe	11215	11215	11215	11215	11215	11215	11215	11215	11215	11215	11215	11215	134579
	PV Generation	Electric	kWhe	147862	112006	94506	57110	20093	4177	1096	1560	16383	53576	103521	133112	745003

Comfort Conditions

Note: The summary of comfort conditions achieved is essential to ensure that the simulation result is representative of a building that successfully maintains conditions; a building that fails to do so will often appear to use less energy, but in practice would not be representative of how the building will actually work.

The table below summarises the number of hours any zone is not within the 20-24°C dry bulb temperature range between 8am and 6pm weekdays. Note that the system design allows for temperatures to drift outside this temperature range.

Table 6 Percentage of Occupied Hours that Zones are Under-Heated or Under-Cooled

	Under-heated	Under-cooled
Centre Zones	0.17%	0.08%
Perimeter Zones	1.36%	0.65%

IES does not allow public holidays to be easily excluded from the binned hours thus the figures above include times when zones are outside the 20-24°C range on public holidays. With 9 public holidays, this bias could be up to 3.4%. Spot checks have confirmed that conditions are being met on peak weekdays thus we are confident the hours where temperatures are outside the nominated range are almost entirely occurring on public holidays when we are not conditioning the building.

We also note that no zone drops below 12°C. The night setback / façade protection mode does operate frequently in perimeter and lobby zones to maintain a minimum of 12°C.

2.5 Sensitivity and Off-Axis Analysis

Note: Off-axis analyses are used to test the sensitivity of the building's performance to potential failure modes in construction and operation, as well as operational differences that might realistically occur in the building in operation. A building that shows robust performance to off-axis scenarios is more likely to be robust in practice. However, it is essential that the scenarios examined are realistically and sufficiently challenging. Often, simulators are tempted not to ask the hard questions of a building's performance. This renders the sensitivity testing far less useful and should be challenged by the Independent Design Reviewer.

The "combined" scenario should only consider items and issues that degrade the building's performance.

The off axis scenarios tested in this report provide a good example of realistic issues that the building may face, such as failure of key energy efficiency measures, extreme weather years and changes in building operation.

In line with the Guide to Design for Performance and best practice simulation, a range of scenarios have been assessed to understand performance risks and the sensitivity to some simulation assumptions. The scenarios are summarised in the tables below. Detailed end use information is provided in Table 7 Off-axis Scenario Summary below.

Table 7 Off-axis Scenario Summary

	Off-axis scenario	NABERS Impact	Margin to 4.5 stars	Margin to 4 stars
1	**Extreme Weather Year** We have used the CIBSE TRY future weather year of 2050 for the UKCP09 High scenario (SRES A1Fi) and 50% file. This scenario most closely aligns with the RCP8.5 2050 median scenario.	**+0.07**	**11.7%**	**26.5%**
2	**Failure of Heat Recovery** These devices could fail where the wheels are not rotating or where controls are disabled or drift out of calibration. This scenario assesses the heat recovery devices on the basement, lobby, and DOAS systems to the office floors being disabled. The fan energy to overcome the HR device pressure drops remains in the model and conditions are not fully maintained as the design of the HVAC systems is reliant on the heat recovery devices resulting in a warmer on-coil design condition for the heating coils.	**-0.64**	**-17.7%**	**1.9%**
3	**Failure of Economy Cycle** In this scenario the economy cycle on the DOAS AHUs is disabled leading to the heat recovery device and heating coil aiming to supply 20C air as a minimum under all operational conditions.	**-0.10**	**4.6%**	**20.5%**
4	**Higher Infiltration** Given the London climate and dominance of heating over cooling, higher infiltration rates are carbon conservative. This scenario adopts the defaults in the Guide to Design for Performance with some modification which is a doubling of average infiltration over the Base Case assumption: • Perimeter Zone: 0.35 Air Changes per hour (ACH) when system off increased to 0.7, 50% of these values when systems on • Centre Zone: 0.175 Air Changes per hour (ACH) when system off increased to 0.35, 50% of these values when systems on	**-0.33**	**-5.1%**	**12.4%**

5	**Failure of Demand Controlled Ventilation** The base case simulation assumes constant DOAS flow of 1.2 L/s/m^2 across all half floors. This scenario assumes the landlord CO_2 sensors fail or the tenant installs CO_2 sensors with no volume modulation and the DOAS systems thus have to provide their design flow of 1.7 L/s/m^2 for all hours	**-0.18**	**1.3%**	**17.7%**
6	**Higher Lighting Run Hours** Section A.12 of the assumptions outlines the run hour assumptions in the base case. This scenario assumes: • Stairwells are on 100% 24/7 • Exterior lighting is on dusk until dawn • Water Closet lighting and lift lobbies are on 24/7 • Plant rooms and back of house areas are left on 24/7	**-0.32**	**-4.4%**	**13.0%**
CMB	**Combined Risk Scenario[1]** • Infiltration @ 0.5 AC/hr at perimeter and 50% of that in centre zone with x 50% in the daytime (0.3 AC/hr time and area weighted • Partial failure of economy cycle (Scenario #3 modified) with full economy cycle limited to 17C rather than 14C supply air temperature. • Heat Recovery Device effectiveness set at 60% (2 x DOAS, Basement and Ground level HRU) • Bias in Office Area Space Setpoints • Failure of demand controlled ventilation (Scenario #5) • Building is 100% conditioned, but only 90% occupied thus rated area at 90% • Miscellaneous mechanical fans run for an additional 3 hrs per working day • Base building lighting operates for an additional 3 hrs per working day when not already on continuously (Scenario #6 modified)	**-0.56**	**-14%**	**5%**

[1] The original report had more off-axis scenarios than listed in this example report. As a result this combined scenario includes some cases that were simulated individually in the original report but not presented here. Normally, the combined scenario would be a combination of scenarios presented in the report.

Detailed Off-axis Scenario Summaries are presented in Table 8 - Table 14. All use the same area and hours figures as the base case.

Table 8 Off-axis Scenario 1: Extreme weather year

	Electricity (MWh)	District Cooling (MWht)	District Heating (MWht)
Space heating	4.3	0.0	806.5
Space cooling	21.0	891.5	0.0
HVAC fans	331.0	0.0	0.0
Tenant supplementary cooling	5.7	240.9	0.0
MEW and Switchroom cooling	31.5	73.2	0.0
Misc House AC	6.5	14.5	8.8
Misc House fans	43.8		
House lighting	195.4		
External lighting	2.3		
Closed Cavity Façade compressed Air	15.2	0.0	0.0
Other House power	39.0		
DHW	44.1	0.0	218.9
Hydraulic pumping	17.2	0.0	0.0
Greywater	7.2	0.0	0.0
Vertical transport	134.4	148.3	0.0
Electrical reticulation losses	18.0	0.0	0.0
On-site generation	-11.9		
Net Base Building Demand	904.7	1368.4	1034.2

Total MWhe	2383
Decimal rating	4.84
4.5 star MWhe	2700
4 star MWhe	3240
Margin to 4.5 star	11.7%
Margin to 4 star	26.5%

Table 9 Off-axis Scenario 2: Failure of Heat Recovery

	Electricity (MWh)	District Cooling (MWht)	District Heating (MWht)
Space heating	11.3	0.0	1852.7
Space cooling	12.9	589.2	0.0
HVAC fans	331.2	0.0	0.0
Tenant supplementary cooling	5.4	248.2	0.0
MEW and Switchroom cooling	31.4	75.4	0.0
Misc House AC	6.5	14.5	8.8
Misc House fans	43.8		
House lighting	195.4		
External lighting	2.3		
Closed Cavity Façade compressed Air	15.2	0.0	0.0
Other House power	39.0		
DHW	44.1	0.0	185.3
Hydraulic pumping	17.2	0.0	0.0
Greywater	7.2	0.0	0.0
Vertical transport	134.2	152.8	0.0
Electrical reticulation losses	17.9	0.0	0.0
On-site generation	-11.9		
Net Base Building Demand	903.4	1080.1	2046.8

Total MWhe	3178
Decimal rating	4.13
4.5 star MWhe	2700
4 star MWhe	3240
Margin to 4.5 star	-17.7%
Margin to 4 star	1.9%

Table 10 Off-axis Scenario 3: Failure of Economy cycle

	Electricity (MWh)	District Cooling (MWht)	District Heating (MWht)
Space heating	5.3	0.0	1049.0
Space cooling	19.2	839.3	0.0
HVAC fans	331.2	0.0	0.0
Tenant supplementary cooling	5.6	247.4	0.0
MEW and Switchroom cooling	31.5	75.2	0.0
Misc House AC	6.5	14.5	8.8
Misc House fans	43.8		
House lighting	195.4		
External lighting	2.3		
Closed Cavity Façade compressed Air	15.2	0.0	0.0
Other House power	39.0		
DHW	44.0	0.0	209.8
Hydraulic pumping	17.2	0.0	0.0
Greywater	7.2	0.0	0.0
Vertical transport	134.4	152.3	0.0
Electrical reticulation losses	18.0	0.0	0.0
On-site generation	-11.9		
Net Base Building Demand	904.0	1328.7	1267.7

Total MWhe	2576
Decimal rating	4.67
4.5 star MWhe	2700
4 star MWhe	3240
Margin to 4.5 star	4.6%
Margin to 4 star	20.5%

Table 11 Off-axis Scenario 4: Higher Infiltration

	Electricity (MWh)	District Cooling (MWht)	District Heating (MWht)
Space heating	8.4	0.0	1530.1
Space cooling	9.0	438.5	0.0
HVAC fans	332.8	0.0	0.0
Tenant supplementary cooling	5.2	253.1	0.0
MEW and Switchroom cooling	31.3	76.9	0.0
Misc House AC	6.5	14.5	8.8
Misc House fans	43.8		
House lighting	195.4		
External lighting	2.3		
Closed Cavity Façade compressed Air	15.2	0.0	0.0
Other House power	39.0		
DHW	44.1	0.0	198.8
Hydraulic pumping	17.2	0.0	0.0
Greywater	7.2	0.0	0.0
Vertical transport	134.1	155.8	0.0
Electrical reticulation losses	17.8	0.0	0.0
On-site generation	-11.9		
Net Base Building Demand	897.5	938.8	1737.7

Total MWhe	2837
Decimal rating	4.44
4.5 star MWhe	2700
4 star MWhe	3240
Margin to 4.5 star	-5.1%
Margin to 4 star	12.4%

Table 12 Off-axis Scenario 5: Failure of Demand Controlled Ventilation

	Electricity (MWh)	District Cooling (MWht)	District Heating (MWht)
Space heating	6.0	0.0	1108.3
Space cooling	11.0	519.3	0.0
HVAC fans	498.8	0.0	0.0
Tenant supplementary cooling	5.3	249.1	0.0
MEW and Switchroom cooling	31.4	75.7	0.0
Misc House AC	6.5	14.5	8.8
Misc House fans	43.8		
House lighting	195.4		
External lighting	2.3		
Closed Cavity Façade compressed Air	15.2	0.0	0.0
Other House power	39.0		
DHW	44.1	0.0	210.1
Hydraulic pumping	17.2	0.0	0.0
Greywater	7.2	0.0	0.0
Vertical transport	134.1	153.3	0.0
Electrical reticulation losses	21.1	0.0	0.0
On-site generation	-11.9		
Net Base Building Demand	1066.7	1011.9	1327.2

Total MWhe	2666
Decimal rating	4.59
4.5 star MWhe	2700
4 star MWhe	3240
Margin to 4.5 star	1.3%
Margin to 4 star	17.7%

Table 13 Off-axis Scenario 6: Higher Lighting Run Hours

	Electricity (MWh)	District Cooling (MWht)	District Heating (MWht)
Space heating	5.7	0.0	1042.4
Space cooling	12.8	584.0	0.0
HVAC fans	331.2	0.0	0.0
Tenant supplementary cooling	5.5	248.4	0.0
MEW and Switchroom cooling	31.4	75.4	0.0
Misc House AC	6.5	14.5	8.8
Misc House fans	43.8		
House lighting	538.9		
External lighting	4.7		
Closed Cavity Façade compressed Air	15.2	0.0	0.0
Other House power	39.0		
DHW	44.1	0.0	212.8
Hydraulic pumping	17.2	0.0	0.0
Greywater	7.2	0.0	0.0
Vertical transport	134.2	152.9	0.0
Electrical reticulation losses	24.7	0.0	0.0
On-site generation	-11.9		
Net Base Building Demand	1250.3	1075.2	1264.0

Total MWhe	2818
Decimal rating	4.45
4.5 star MWhe	2700
4 star MWhe	3240
Margin to 4.5 star	-4.4%
Margin to 4 star	13.0%

Table 14 Off-axis Scenario: Combined

	Electricity (MWh)	District Cooling (MWht)	District Heating (MWht)
Space heating	8.7	0.0	1489.2
Space cooling	12.2	549.2	0.0
HVAC fans	499.0	0.0	0.0
Tenant supplementary cooling	5.6	251.6	0.0
MEW and Switchroom cooling	31.5	76.4	0.0
Misc House AC	8.4	14.5	8.8
Misc House fans	57.7		
House lighting	240.7		
External lighting	3.1		
Closed Cavity Façade compressed Air	15.2	0.0	0.0
Other House power	39.0		
DHW	44.1	0.0	196.9
Hydraulic pumping	17.2	0.0	0.0
Greywater	7.2	0.0	0.0
Vertical transport	134.3	154.9	0.0
Electrical reticulation losses	22.5	0.0	0.0
On-site generation	-11.9		
Net Base Building Demand	1134.3	1046.7	1694.9

Total MWhe	3078
Decimal rating	4.21
4.5 star MWhe	2700
4 star MWhe	3240
Margin to 4.5 star	-14.0%
Margin to 4 star	5.0%

2.6 Energy Coverage and Metering Arrangements

Where sub-meters (and thermal meters) will be used to calculate a NABERS rating, it is important that the Simulator considers the associated operational risks and can demonstrate that the proposed metering arrangement allows energy capture and exclusions in line with the Rules.

If the effects of sub-meters (in particular thermal meters) not functioning as designed -leading to all exclusions measured by that meter being included in a rating – are not considered for projects relying on this equipment for a large proportion of exclusions, the targeted rating may be at significant risk.

This section outlines:

- Section 2.6.1 describes the assumed primary metering methods with marked up schematics to show the principles that would apply.
- Section 2.6.2 - Beyond the above principles, there are several areas that need to be discussed with the client and design team and an approach agreed that balances cost, complexity and potential NABERS Energy rating impacts.

2.6.1 Primary Metering Arrangements

The following schematics have been reviewed along with the distribution board, mechanical services switchboard schedules to determine the meters that the NABERS Energy rating will be reliant on:

- Electrical single line diagrams - EL-61-131 and EL-61-132
- Low Temperature Heating Hot Water (LTHW) Schematics - ML-56-131_iss2_revC00, ML-56-132_iss2_revC00, ML-56-133_iss1_revC00
- Chilled Water (CHW) Schematics - ML-55-131_iss2_revC00, ML-55-132_iss2_revC00, ML-133_iss1_revC00
- There is no base building gas use nor reliance on water meters for NABERS Energy
- Diesel has not been reviewed at this time due to its immaterial impact if for testing and emergency purposes.

There are operational risks associated with the use of sub-meters to calculate NABERS ratings, for example relating to commissioning, record-keeping, reliability and accuracy across the full load range. In general, ratings that rely on thermal metering are more likely to be problematic. A meter management plan should be developed to identify and mitigate these risks.

2.6.1.1 Electricity

To ensure ease in determining the minimum energy coverage on NABERS Energy, we recommend the two private / non-utility low-voltage meters (Type B) are used as the utility meters for NABERS Energy purposes as allowed under 3.4.2 of the Metering and Consumption Rules (v1.0). From these two meters, there are several deductions of excluded energy use. With reference to the coloured single line diagram in Appendix C, the deductions would involve:

- NABERS utility meters – sum of the two Type B meters to ensure 100% coverage of base building electricity (purple area)
- Deduct all retail tenant electricity use – currently 10 Type C meters (Tan areas)
- Deduct all commercial tenant electricity use – currently captured by two Type C meters on the north and south rising mains (Green area)

- Monitoring other spares and future electrical connections for end uses that are eligible to be excluded under NABERS.

We recommend the above approach over adding 30+ Type C non-utility meters as there are fewer meters to deduct and the method will naturally encourage validation of metering systems and monitoring of unmetered legs. The method also avoids the losses between the HV utility meters and LV meters proposed which should not be included in the rated energy.

The current metering arrangements will allow the integrity of the meters to be collectively monitored by comparing the sum of primary meters to the sum of secondary and flagging when the difference varies by more than the expected losses / accuracy of meters. This doesn't replace the NABERS validation requirements but does assist as an ongoing maintenance practice.

2.6.1.2 Chilled Water

The chilled water is supplied to the Example Tower building by the utility with the utility thermal meter on the utility side of the consumer heat exchanger.

A landlord private primary thermal meter exists on the building side of the heat exchangers.

From the utility thermal meters, the load types that factor into the NABERS Rated energy calculation are:

- **Retail tenant CHW use** – individual thermal meters exist at the tenant heat exchangers and can be deducted from the base building thermal energy. Losses upstream of the meters will be base building, but the downstream thermal energy can be deducted.
- **Tenant computer rooms** – where these are fitted with thermal meters, the thermal energy provided to these spaces is used in a benchmark correction at a standard COP of 2.5.

Ideally the retail CHW connections could be supplied from a dedicated CHW branch that is more easily metered in one location for NABERS deduction purposes.

2.6.1.3 Heating Hot Water

Similar to chilled water, the low temperature heating water (LTHW) is supplied to the Example Towers building by the utility with the utility thermal meter on the utility side of the consumer heat exchanger.

A landlord private primary thermal meter exists on the building side of the heat exchangers.

From the utility thermal meters, there are two loads that are eligible for deduction from the NABERS Rated energy calculation:

- **Retail tenant LTHW use** – individual thermal meters exist at the tenant heat exchangers and can be deducted from the base building thermal energy. Losses upstream of the meters will be base building, but the downstream thermal energy can be deducted.
- **Tenant Kitchen Exhaust Make-up air system heating** – at roof level, heat exchangers and thermal meters exist for the future tenant's use. The kitchen exhaust provisions are spatial only by the landlord and any tenant system would be dedicated to a single tenant. Under 6.2.3.2 of the NABERS UK The Rules – Energy for Offices, the fans and the heating would be eligible for exclusion from the minimum energy coverage.

Ideally the retail LTHW connections could be supplied from a dedicated LTHW branch that is more easily metered in one location for NABERS deduction purposes.

2.6.2 Metering and Minimum Coverage Issues to Resolve

The table below summarises critical energy coverage and metering issues that a high NABERS Energy rating is reliant on. Some of these issues are addressed sufficiently in the design but require monitoring. Other issues are for consideration where the client and design team need to make a value judgement on the value of additional metering or changes to metering to protect or maximise the NABER Energy rating potential.

Table 15 NABERS Metering Requirements and Comments

#	End Use	Inclusion/ Exclusion	Issue	Potential Impact
1	Retail Tenant Electricity	Exclusion	• Metering is sufficient, however consider whether switchboard / busbar metering could be configured to reduce the number of meters (currently 10 meters) required to enable this exclusion.	Very Significant
2	Office Tenant Electricity	Exclusion	• Metering is sufficient, however note items 6 7, and 9	Very Significant
3	Retail thermal energy	Deduction	• The thermal metering for LTHW and CHW is sufficient, however consider dedicated branches to simplify NABERS thermal exclusion. Note item 4 to maximise the deduction.	Very Significant
4	Retail pumping energy	Deduction	• To maximise the deduction of retail energy use, we recommend the primary low temperature heating pumps and chilled water pumps be separately metered as a group so that the pump energy use can be proportionately excluded should the owners choose to. • The CHW pumps are currently isolated on MCCP-B1.05 so sufficient as the sub-main is metered. • The LTHW pumps are supplied from MCCP-B1.01, however CCU-B1.01 is also on this board and should be moved to another board if possible or that equipment metered to allow a deduction from the sub-mains sub-meter.	< -.01 Stars

5	Computer Server Room CHW	Inclusion	• The tenant fit out CHW allowance of 10 Wr/m^2 is not intended for computer rooms. However, if a tenant were to use it for computer room cooling during business hours, the CHW energy use should be metered. • Under 6.2.3.3 of the NABERS UK The Rules – Energy for Offices, the benchmark energy is adjusted upwards using the above thermal meter for computer server rooms. • Note any base building energy use associated with data centres should be metered and excluded in entirety.	0 to -0.2 Stars depending on size of server room load
6	Tenant Fan Coil Units	Inclusion	• The energy model assumes these fans are wired to the Landlord's house board; however, it is common industry practice to wire these to the tenant's board. Currently the Cat A specification does not require sub-metering of these loads by the tenant – this should be reviewed with the developer. This equipment could be added to the Rated Energy via private sub-meters within each tenant board. Preferably, the fans are supplied from a section of the board that also contains the CHW and LTHW pumps, so it is one meter per tenant that is being added. • Section 7.2.1 of the NABERS UK the Rules - Metering and Consumption allow a default allowance to be deemed which based on 50.16 rated Hours would be 5.43 kWh/m^2 pa. As this is slightly higher than the simulated electricity use of 4.31 kWh/m^2 the default presents a small penalty. • However, if variable fan speed control is used for the tenant FCUs down to 70% volume at part loads, the penalty of using the default would be more significant.	-0.04 to - 0.10 Significant
7	Tenant CHW & LTHW Pumping	Inclusion	• The energy model assumes these pumps are wired to the Landlord's house board; however, it is common industry practice to wire these to the tenant's board. Currently the Cat A specification does not require sub-metering of these loads by the tenant – this should be reviewed with the developer. Note comment above of gathering this base building equipment to one portion of the tenant's board	-0.18 Significant

			to enable metering and addition to Rated Energy. • Section 7.2.1 of the NABERS UK the Rules - Metering and Consumption allow a default allowance to be deemed which based on 50.16 rated Hours would be 5.43 kWh/m² pa. As this is much higher than the simulated electricity use of 0.31 kWh/m² the default presents a significant penalty.	
8	Tenant kitchen exhaust Make-Up Air Heating	Exclusion	• The landlord provides the spatial provision for the tenant to supply their own kitchen exhaust systems. Under 6.2.3.2 of NABERS UK The Rules – Energy for Offices, tenant local pollutant ventilation fans can be excluded as is the case with the kitchen exhaust fans and make-up air fans for kitchen exhaust. • Given this the heating connection for the make-up air fans can also be excluded. Thermal meters are proposed as part of the tenant heat exchanger connections for HX-KMAF-RF.01/.02 which will be sufficient to exclude this energy use	Moderate
9	Typical Floor House Light & Power	Inclusion	• Lighting and small power in lift lobbies, water closets, house corridors and back of house areas are all base building energy use. • The preference is for these loads to be supplied from the landlord's house board. • However, some industry practices may be to supply these loads from the tenant's board. There is no provision in the Rules to apply a default for these energy end uses. Thus, in this scenario, either all the tenant electricity must be included in the Rated Energy (catastrophic impact on rating) or the loads must be separately metered and added to the rated energy. In the latter scenario the energy use does not count in the NABERS error calculation but would involve many meters that require maintenance and management.	Critical (worse case all tenant electricity would have to be added to Rated Energy)

Appendix A Building Assumptions

Note: In this section the simulator provides extensive details about practically every aspect of the simulation and associated input assumptions. This provides excellent insight into the assumptions of the model and makes the simulation far more useful to the reviewer and, indeed, the other clients of the simulator.

A.1 Introduction

This document details the assumptions underlying the Base Case building energy model for the Example Towers, 1 Test St, London W1 for the purposes of providing a NABERS Energy prediction against a standard set of assumptions. The energy model has been based on a combination of spreadsheet type calculations and advanced energy simulation using the IES Virtual Environment (Apache) energy simulation software.

A.2 Documentation

The assumptions outlined here align with the mechanical, façade and lighting design as outlined within Stage 4 documentation. Revisions to key documents used as inputs are noted in the table below.

Table 16 Key Documentation Forming Basis of Model

Document(s)	Revision	Purpose
Area Schedule AL-01-002	Rev. C00 12-Apr-20	• Area schedule to compare to model area and confirm Rated Area
Façade Types Elevations AL-DR-25 series	C00 for Contract 04-Aug-20	• Façade geometry and types
Bay Studies AL-DR-25 series	C00 for Contract 04-Aug-20	• Façade geometry and types
General Assembly Plans AL-DR-20 series	C00 for Contract 12-Apr-20	• Floor geometry, zoning and separation of conditioned area from back of house and retail areas
Thermal Line Drawings AL-DR-14 series	C00 for Contract 12-Apr-20	• Primary and secondary thermal boundaries for conditioned spaces

Façade Performance Specification AL-SP-00-01	T01 for Contract 31-Jan-20	• Specified system U-Values and SHGC / g-values
Façade Sub-Contractor Thermal Calculations AL-RP-25 series	T01 for Contract 22-Mar-19	• Confirmation of likely system U-Values and g-values.
Internal Wall Typical Details AL-DR-22 series	C00 for Contract 12-Apr-20	• Build ups for internal walls • Insulation thickness
Floor Finishes Typical Details AL-DR-43 series	C00 for Contract 12-Apr-20	• Build ups for internal floors • Insulation thickness
Roof Typical Details AL-DR-27 series	C00 for Contract 12-Apr-20	• Build ups for roof terraces and roofs • Insulation thickness
Mechanical Services Shell & Core Specification ML-00-151	C01 for Contract 26-Jul-20	• Design criteria for equipment sizing • Equipment schedules • Controls sequences • Insulation thicknesses
Hydraulic Services Shell & Core Specification	C01 for Contract 26-Jul-20	• Pump schedules • DHW system arrangements
Lighting Layouts and Schedules EL-DR-63 series for internal lighting EL-DR-25-863 for external lighting	C00 for Contract 12-Apr-20	• Fixture types, control circuits by functional area
Electrical Services Shell & Core Specification EL-SP-00-151	C00 for Contract 12-Apr-20	• Luminaire types and wattages
Electrical Services CAT A Specification EL-SP-00-251	C00 for Contract 12-Apr-20	• Luminaire types and wattages
Mechanical Services Shell & Core Layouts ML-DR-57 series	C00 for Contract 26-Jul-20	• Zoning and system arrangements for basement, ground level and typical floor landlord areas (Amenities etc)
Mechanical Services Cat 'A' Layouts ML-DR-57 series	C00 for Contract 06-Nov-19	• Representative zoning for typical tenant fit out, informed IES thermal zoning

A.3 Site

A.3.1 Weather

The CIBSE London TRY weather data has been utilised in the annual analysis which is based on Heathrow Airport measurements.

For the future climate off-axis scenario we chose to use the 2000 Special Report on Emission Scenarios (SRES) scenario A1Fi median prediction for 2050. Through 2009 this file was classified as a 'High' emissions scenario by the UK Met office. The SRES A1Fi scenario is the SRES scenario that most closely aligns with the RCP8.5 scenario which Lendlease uses for climate risk planning.

A.3.2 Surrounding Context

The orientation has been taken from the site plan with project north being 45 degrees East of North.

A ground reflectance of 20% has been assumed.

Reflectance of all surrounding buildings and external shades is 30% as per the in-built parameters within IES. The figure below illustrates how the surrounding buildings have been represented in the energy model.

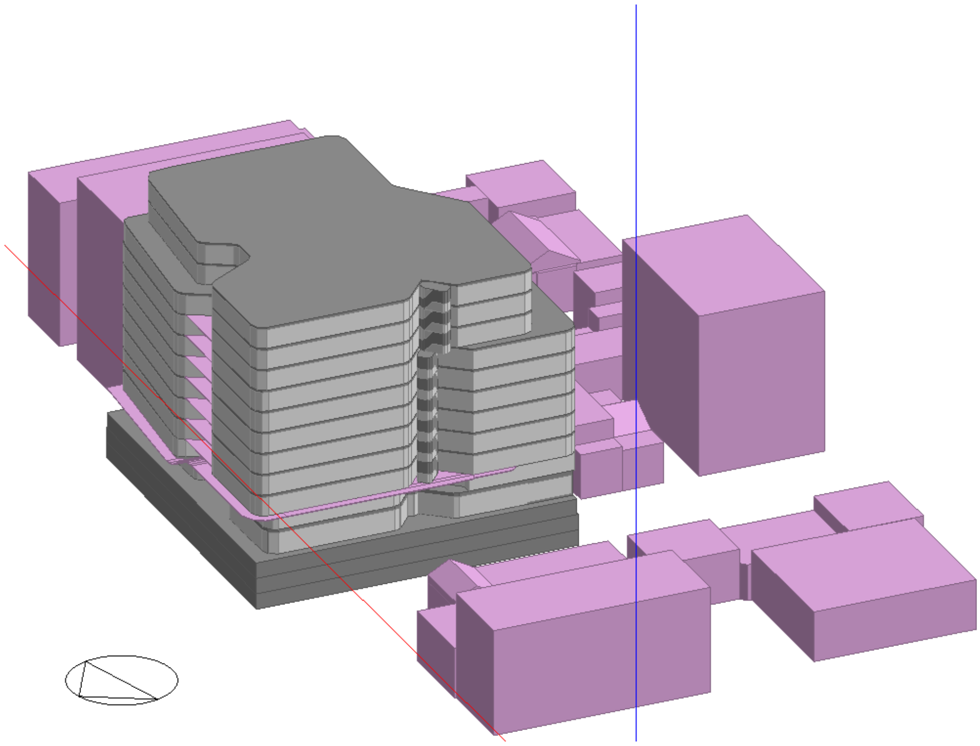


Figure 3 Example Tower and Surrounding Buildings from North West (note: For confidentiality reasons, this image is from a different and unrelated project)

A.4 Form

A.4.1 Vertical Zoning

All floors of the proposed building have been modelled as per the Stage 4 documentation. Floor to floor height is typically 3,900mm. Ceiling spaces have not been modelled as return / relief air plenums and therefore all internal loads are allocated fully to the conditioned space with the thermal mass decoupled from mechanical air streams.

A.4.2 Windows & Shading

The model assumes floor to ceiling window systems for the typical floor in line with elevations.

There model incorporates where vertical strips of wall area exist and some floors where a spandrel zone does exist also in line with the building elevations.

The expressed fins on façade type EWS-01 (of 300mm depth) and mullions on façade type EWS-03/04 (of 150mm depth) provide articulation to the façade. These have not been modelled as shades although the higher U-Value arising due to increased thermal bridging has been incorporated. In a cooling climate this is conservative, but in a heating climate it may be optimistic. We note the lower portions of the building experience significant site shading due to the S5 and S9 buildings and where this shading occurs, the impact of not including the fins would be minor.

A.4.3 Area

The building's measured Net Internal Area (NIA) in design is 32,882 m^2 NIA including 293 m^2 in the common ground floor lobby and excluding retail & leisure. The maximum NABERS Rated Area should be 32,589 m^2 NIA as the public lobby is not included in the Rated Area definition.

The IES model's conditioned office area is 32,776 m^2, which aligns well (-0.32%) with the building's actual NIA. In addition to the conditioned NIA, the model allows for conditioning to water closets, basement and back of house areas that are not part of NIA and Rated Area.

A.5 Constructions

A.5.1 Walls, floors and roofs

The table below presents the constructions used for the building fabric elements. In line with the façade performance specification and architectural wall and roof details.

Table 17 Opaque Constructions

Type	Location	Element	Construction (outside to inside)	R-Value (m^2K/W)	Solar Absorptance (outside/inside)
External Walls**	Ground Floor Lobby	EWS-15	3mm Rainscreen+ 50mm Air Gap + 75mm Insulation + 12.5mm Rainscreen	3.1	0.70 / 0.55
	Basement	Primary Walls	140mm Brickwork + 10mm Air Gap + 97mm Insulation + 15mm Gypsum	3.7	0.70 / 0.55
Interior Walls (partitions)	Typical	Inter-zone partition (separates thermal zones)*	12mm Plasterboard + 90mm Air Gap + 12mm Plasterboard	0.3	0.55 / 0.55
		Internal wall to non-conditioned spaces	300mm Concrete (adiabatic) + 90mm Air Gap + 12mm Plasterboard	0.3	0.60 / 0.60
	Basement	Secondary Walls	140mm Brickwork + 10mm Air Gap + 70mm Insulation + 15mm Gypsum	3.7	0.70 / 0.55
Interior Floors / Ceiling	Typical Office Floor / Ceiling	Floor / ceiling between conditioned office spaces	6mm Carpet + 31mm Access Floor + 150mm Air Gap + 300mm Concrete + 400mm Air Gap + 12mm Ceiling Tiles	0.9	0.55 / 0.55
	Typical WC Floor / Ceiling	Floor / ceiling between conditioned WC spaces	12mm Tiles Carpet + 300mm Concrete + 400mm Air Gap + 12mm Ceiling Tiles	0.4	0.55 / 0.55
	Ground Floor Lobby	Lobby to Basement	10mm Concrete Tiles + 100mm Screed + 300mm Concrete + 95mm Insulation	3.6	0.55 / 0.55

Roof	Typical Roof	Conditioned Space with Roof	50mm Concrete Paviour + 108mm Air Gap + 180mm Insulation + 12mm Membrane + 350mm Concrete + 300mm Air Gap + 12mm Gypsum	6.7	0.70 / 0.55

* This construction type has been used to represent a worst case to create load diversity between the centre zone and perimeter zones. An open plan arrangement should achieve a better result in terms of energy usage and peak perimeter loads due to increased air mixing between zones, which will lead to more homogenous / neutral loads.

** Not all external wall types to unconditioned spaces (i.e. lift motor rooms) have been modelled, but these are typically insulated.

A.5.2 Glazing

The properties for the glazing used in the model are displayed below. IES uses spectral average properties for each individual glass layer and then modifies the system properties as angle of incidence changes accounting for the refractive index and inter-reflection between glazing panes.

Table 18 Glazed Constructions. Calculated performance values have been taken from the façade contractor's documentation, as these were more conservative (lower performance) that the façade consultant calculations.

Type	Description	Centre of Glass SHGC / G-value	System U-Value (Glass + Frame)
EWS 01/02	Double glazed unitised system with fins	0.31	1.6
EWS 03/04	Closed cavity façade with interstitial blinds	0.50 / 0.13 (with blinds down)	1.2
EWS 05/07	Double glazed unitised system	0.36	1.4
EWS 06A/08	Double glazed unitised system	0.29	1.7
EWS 10-13, 17-18 and 21	Double glazed unitised system	0.36	1.4

The interstitial blinds within EWS 03/04 are assumed to drop when incident solar on the façade exceeds 250 W/m^2 and are raised when this falls to 100 W/m^2.

Internal blinds are used for other glazed office areas with exception of the water closets; however, a SHGC / g-value modifier of 0.75 is assumed in these areas thus only a marginal decrease in solar gains. Controls are as per the interstitial blinds on the CCF system.

A.5.3 Infiltration

Infiltration volumes assumed for office areas are stated below.

- Perimeter Zones

- 0.175 Air Changes per Hour when air handling plant is operating
- 0.35 Air Changes per Hour when air handling plant is not operating

- Centre Zones
  - 0.088 Air Changes per Hour when air handling plant is operating
  - 0.175 Air Changes per Hour when air handling plant is not operating

These values are not dependent on the local wind conditions and are therefore constant within the simulation. This is considered a conservative assumption as infiltration will be lower at typical wind conditions.

The ground level main foyer is modelled with a business hours infiltration rate of 0.85 Air Changes per hour which aligns with 250 L/s per revolving door + 15%. Outside the working day 7am-6pm period the infiltration rate is assumed to be 0.5 Air changes per hour.

0.25 air changes per hour is allowed for in the end of trip during the 6am-7pm working day period with 50% of that outside that period.

A.5.4 Internal loads

Internal heat loads are summarised in the table below. The lighting and equipment energy use in office areas is part of tenant light and power use and thus is not directly included in the base building energy use prediction. The heat gains associated with this energy use do however directly impact the space heating and cooling loads and thus the base building air conditioning system energy use. Both the design density (i.e. system capacity) and the operational density (i.e. assumption in the model) are included.

As described in Section 2.4.3.2 internal load diversity has been modelled using two internal load profiles (high and low), but in the process varying not just equipment load but also lighting load and occupant density.

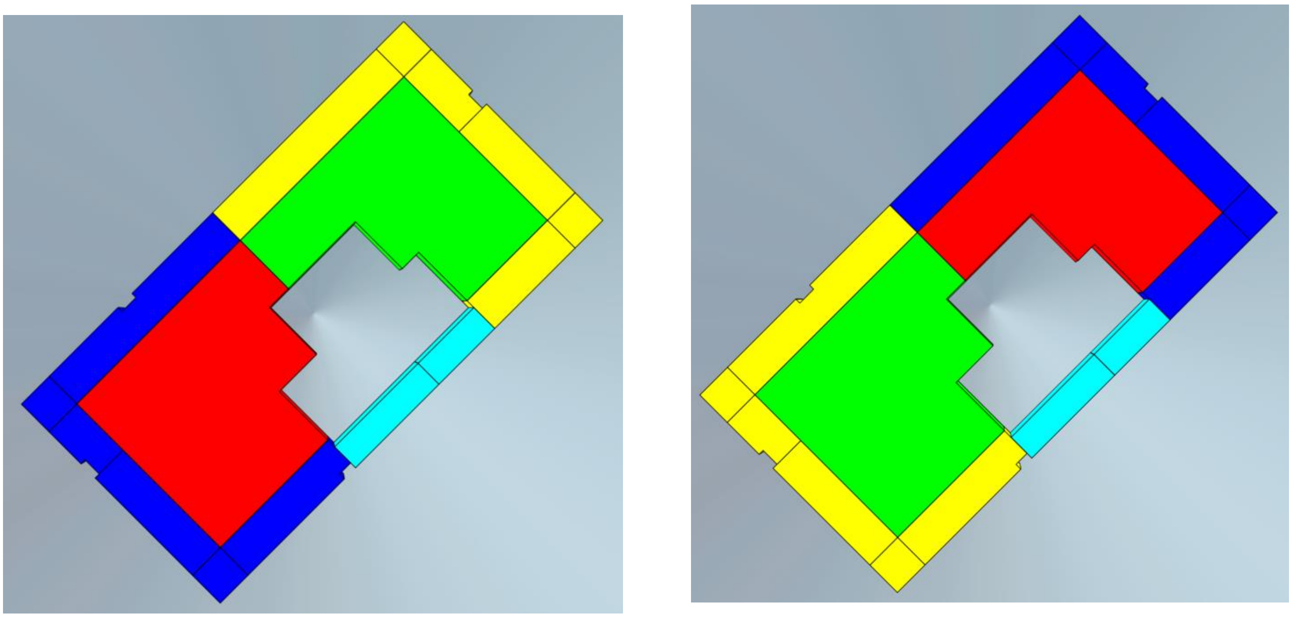
Table 19 Internal Load Assumptions

Load Type	High Load Office Zones	Low Load Office Zones	Ground Lobby	End of Trip
Work point Density (m^2/work point)	8	12	N/A	N/A
Average Work point Utilisation*	70%	70%	N/A	N/A
Effective Average Occupant Density (m^2/p)	11.4	17.1	10 people on average (40 at 25% average)	6 people on average (25% of 31 showers)
Lighting (W/m^2)	10	4	10	5
Equipment (W/m^2)	11.3 (2.5 fixed + 100W/person variable)	6.7 (2 fixed + 80W/person variable)	Included in lighting	0

* Average during business hours in line with NABERS defaults

The ground lobby and end of trip are assumed to have no occupant loading outside the 6am-7pm period. 15% of the light and power load is assumed to be present outside that period.

The model images below show how the high and low load settings alternate between half office floors. We have not varied the high and low load zones within the half floors in part as we have internal partitions that insulate between zones and each zone is serviced by a dedicated FCU such that no reheat or recool occurs other than that which may be introduced by DOAS supply temperatures that do not align with zone needs.



Key: Red Zone = High Load Centre Zone
Green Zones = Low Load Centre Zone
Dark Blue Zones = High Load Perimeter Zone
Yellow Zones = Low Load Perimeter Zone
Light Blue Zones = WC Zone

Figure 4 : High and Low Internal Load Distribution (L06 Left and L07 Right)

A.6 Operational Profiles

The default schedules in Section 8 of the *Guide to Design for Performance* have been utilised when scheduling HVAC operation and internal heat gains. The schedules are not repeated here as they are available in the guide. The schedules align with the following operational profile:

- 8am-6pm Monday to Friday normal established building hours (50 hours/week). In Australia, if established building hours are extended the NABERS rating tends to not be negatively impacted – tighter established building hours tends to predict a more conservative rating. While not proven to be the case in the UK, we have assumed 50 hours is more conservative than 60.
- The air handling plant starts at 7am on all working days to pre-condition the space.
- The standard UK public holiday schedule available in IES has been used which does not operate the HVAC systems for 8 weekdays across the year.

- Level 17 represents approximately 5% of the net internal area and is simulated with Saturday morning loads and HVAC operation from 9am-12pm in line with Section 8 of the Guide.

The ground lobby area is assumed to operate from 7am through 6pm workdays, while the End of Trip facilities are assumed to operate from 6am through 7pm on working days.

A.7 Air Distribution

In line with the mechanical design, the IES model contains the following key systems:

- Basement tempered air system with heat recovery and heating and cooling tempering coils. The end of trip has a zone heating coil to maintain minimum temperatures.
- Main Foyer is modelled with the heat recovery unit tempering the outdoor air and the AHU coils providing heating and cooling to a relaxed temperature band. Trench heaters provide the first source of heating. We have not modelled the event mode economiser as the infiltration volume we have modelled is significant relative to the event mode economiser volume and we wanted to avoid any double counting.
- Dedicated Outdoor Air Systems (DOAS) provide tempered ventilation air to the main office levels. These systems contain heat recovery devices and heating and cooling coils to temper the ventilation air
- Fan Coil Units meet space heating and cooling needs through the office areas.

The conditioned areas and HVAC system zoning have been modelled as per the mechanical design documentation with the following simplifications in the main office areas:

- Zoning as outlined in Section A.4.3 noting we have two perimeter zones on each major orientation where in practice there would be multiple and that centre zones are combined into two zones within the model.
- The North and South air handlers are combined so that a single DOAS is modelled for the low rise and high rise to simplify ApHVAC model development, multiplexors and model QA.

The fan, coil and heat recovery inputs for IES were developed from the mechanical design documentation. Representative internal unit pressures and efficiencies were assumed to match the minimum specific fan powers specified as outlined in the table below. We understand that specific fan power as defined by Part L is circuit watts and includes all drive, motor and controls losses. Our assumptions are thus conservative as motor efficiency is not included in the specific fan power comparisons in table below.

Table 20 Fan Pressure and Efficiency Assumptions

	DOAS AHUs (Typical)		Basement AHU		Ground AHU		Ground HRU		FCUs	
Unit Tag	AHU-01.01/.02 and AHU-RF.01/.02		AHU-B1.01		AHU-00.01		HRU-00.01		NA	
	Supply	Relief	Supply	Relief	Supply		Supply	Relief		
Scheduled Data										
Duty Volume (L/s)	Varies	Varies	3,470	3,450	4,000		510	440	Varies	
Scheduled External Static (Pa)	400	400	300	300	300		200	200	30	
Fan Type	Plug	Plug	Plug	Plug	Plug		Plug	Plug		
Motor Size (kW)	30	30	4	4	5.5		2	2	Varies	
	Cooling Coil	Heating Coil	Cooling Coil	Heating Coil	Cooling Coil	Heating Coil		Heating Coil	Cooling Coil	Heating Coil
Air On (°C)	27.5	7.0	30.0	10.0	25.0	16.0		-4.0	24.0	20.0
Air Off (°C)	20.0	20.0	19.9	20.1	16.0	27.0		22.0	13.0	31.0
Coils - CLG	Yes	No	Yes	No	Yes		No	No	Yes	
Coils - HTG	Yes	No	Yes	No	Yes		Yes	No	Yes	
Heat Recovery Wheel	Yes	Yes	Yes	Yes	No		Yes	Yes	No	
Maximum Specific Fan Power (W/(L/s)	1.9	Combined	1.9	Combined	1.7		1.9	Combined	0.2	Average
Filters	M5 Bag, F7 Panel, F8 Carbon	F7 Panel	M5 Bag, F7 Panel	F7 Panel	M5 Bag, F7 Panel, F8 Carbon		F7 Panel	G4 Bag	EU3 Washable	
Model Assumptions										
External Static Pressure (Pa)	375	250	300	300	300		200	200	30	
Cooling Coil (Pa)	75	-	75	-	75		-	-	65	
Heating Coil (Pa)	25	-	25	-	25		35	-	20	
Filters (Pa)	250	30	125	30	300		125	30	15	
HR Coil (Pa)	200	200	230	230	-		230	230	-	
Velocity Pressure (0 for Plug Fans)	-	-	-	-	-		-	-	-	
Total Pressure	**925**	**480**	**755**	**560**	**700**		**590**	**460**	**130**	
Fan Shaft to Air Efficiency (%)	75%	75%	72%	72%	72%		72%	72%	65%	
Motor / Drive Efficiency (%)	85%	85%	85%	85%	85%		85%	85%	85%	
Specific Fan Power (W / (L/s))	1.23	0.64	1.05	0.78	0.97		0.82	0.64	0.20	
Code Comparable Specific Fan Power (W / (L/s))	**1.87**	OK	**1.83**	OK	**0.97**	OK	**1.46**	OK	**0.20**	OK
IES Inputs										
Total Pressure (Pa)	**925**	**480**	**755**	**560**	**700**		**590**	**460**	**130**	
Total Efficiency	**63.8%**	**63.8%**	**61.2%**	**61.2%**	**61.2%**		**61.2%**	**61.2%**	**55.3%**	
Base Case Volume Control	Demand Controlled Ventilation		Constant volume		Constant volume		Two volumes depending on Event mode for Lobby AHU		Constant	
Fan Curve	"EDR Good SP Reset VSD fan"		"EDR Good SP Reset VSD fan"		"EDR Good SP Reset VSD fan"		"EDR Good SP Reset VSD fan"		"EDR Good SP Reset VSD fan" in case we allow this to	
Heat Recovery	73% Effectiveness, 0.5 kW electric input		73% Effectiveness, 0.5 kW electric input				73% Effectiveness, 0.5 kW electric input			

Heat recovery devices are specified as total heat recovery wheels and can thus provide beneficial heating and cooling and will partly humidify winter air. No bypass of heat recovery device is assumed thus all fan pressure is assumed within the main supply and relief fans.

The "EDR Good SP Reset VSD fan" part load curve built into IES ApHVAC is assumed for both supply and relief / return fans. This curve aligns with duct static pressure reset in our experience equating to a power law exponent of between 2.2 to 2.7 on the flow ratio depending on the part load point. Note that most of the systems operate at duty volume as noted by the 'Base Case Volume Control' assumption above. The good static pressure reset curve has no effect in these cases but has been selected to ease assessment of design opportunities should variable flow control be considered as an opportunity.

The high rise dedicated outdoor air system operates on Saturday where it is estimated that the floor in use seeks approximately 5% of the design air volume of the system. The model is optimistic in how it handles fan energy in this scenario with the fan allowed to turn down to the desired volume and the fan power assumed to be linear between the 20% fan input point and 0%.

The mechanical specification calls up for the air handlers to not operate below 25% of duty speed. With duct static pressure reset proposed, we believe this minimum operating point can be significantly lowered to 15% if not lower during on-site commissioning. We also encourage the design team to consider electrically commutated / digital motors to directly drive the plug fans and avoid belt drives as noted in specification. The team should also consider multiple plug fans with discharge dampers to allow the AHUs to turn down well below 15% and closer to 5% duty volume.

If these design features cannot be incorporated, then the system may be required to be designed with a central bypass around the air handlers or additional floors / zones would have to be conditioned to allow the AHU to operate above its minimum volume during after-hours air conditioning. While this arrangement allows a single floor to operate it does not reduce the NABERS risk.

A.7.1 Zoning and System Capacity

To simplify the model as much as possible without materially affecting the accuracy of calculations, many thermally similar centre zones have been combined. Every perimeter zone is assumed to have a 4,500mm zone depth in IES as specified by the project team. Corner zones have been explicitly modelled and the primary perimeter zone orientations have been split into two zones to allow load and solar diversity to be accounted for. Water closet zones are explicitly modelled on each level.

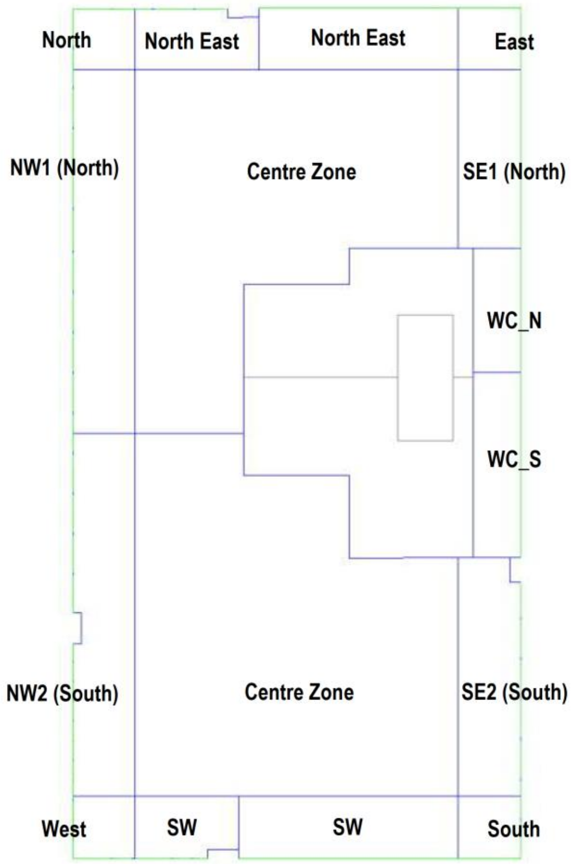


Figure 5 Typical low-rise floor plan showing zoning

The zone system airflow and water-based capacity dictate the available zone cooling capacity and set the fan coil unit (FCU) operating volumes within the model. The FCU capacities have been set consistent with the per m^2 allowances from the mechanical schedules and Cat 'A' typical fit out. The capacities have been checked against façade thermal performance, infiltration and internal load allowances. Roof loads are added to the upper levels that have exposed roof or terraces above. Typical floor capacity allowances used within IES are shown in the table below. The FCU supply airflow rate is dictated by the cooling load in all cases. A single set of controllers and off-coil conditions have been used in IES to cover all zone capacities and ease modelling time.

Table 21 Fan Coil Unit Capacities

Orientation	Zone Type	IES FCU Inputs Cooling Capacity (Wr/m2)	Heating Capacity (Wt/m2)	Supply Flow (L/s/m2)
NE	Perimeter	89.8	49.8	8.17
SE1 (North)	Perimeter	128.3	49.8	11.67
SE2 (South)	Perimeter	116.9	49.8	10.63
SW	Perimeter	113.8	49.8	10.34
NW1 (North)	Perimeter	114.1	49.8	10.37
NW2 (South)	Perimeter	107.2	49.8	9.75
North	Corner	113.8	89.1	10.35
East	Corner	192.0	89.1	17.45
South	Corner	149.9	89.1	13.62
West	Corner	159.2	89.1	14.47
CZ	Centre	36.8	24.0	3.34
Simulation Off-Coil @ 100% Duty (DegC)		14.5	27.0	

A.7.2 System Losses

The supply fans are in a draw through arrangement with the motors in the supply stream thus the fan heat gain occurs after the air has passed through the cooling coil. All the energy input to the motor is assumed to dissipate as heat into the airstreams. Simulated DOAS AHU fan heat gain is typically 0.8°C on each air handler at design duty.

No ductwork thermal losses are modelled as the DOAS systems provide a neutral temperature down the duct and thus UAΔT losses will be minimal.

Duct air leakage is modelled as a bypass of 5% of the hourly supplied airflow. The bypass occurs after the fan to capture all active heating, cooling and fan energy and is discharged into the exhaust air stream so is assumed to be unavailable for heat recovery.

Any loss from ductwork on the FCU systems would be largely recirculated (recovered) given the return / relief air plenum arrangement on the typical floors.

A.7.3 Control Sequences

Control sequences for the simulation have been determined from the mechanical specification. The general logic for the base case is summarised below.

A.7.4 Dedicated Outdoor Air Systems

A.7.4.1 Outdoor Air Control

Demand controlled ventilation is implemented by fixing the business hours outdoor airflow to each zone based on occupant density. As per section A.5.4, occupant density varies 11.4 m^2/person and 17.1 m^2/person in operation with a 14.3 m^2/person average during business hours. We have assumed 1.2 L/s/m^2 for each floor and thus zone when the DOAS systems are running based on the following assumptions:

- Ambient CO_2 concentration of 400ppm and maximum space setpoint of 800ppm

- 0.31 L/min at 1.2 MET CO_2 generation rate per occupant in line with ASHRAE 62 Appendix C. We consider this conservative as a lower average MET and thus lower CO2 generation rate will likely be realised in operation.
- Above would suggest 12.9 L/s/person to achieve 800ppm which at an average 14.3 m2/person equates to 0.9 L/s/m^2.
- However, the base building equipment includes a single VAV box per half floor and single relief air CO_2 sensor detecting the floor average. For this reason, we have assumed the relief air CO_2 would need to lower CO_2 setpoint. If we supply 1.2 L/s/m^2 to each half floor, then that allows for 17.2 L/s/p on average or 700ppm average relief air CO2.
- Above ventilation rate would allow for the 12.9 L/s/person and 800ppm to be met within any zone that is occupied with a density up to 10.7 m^2/person which would equate to 8 m^2/work point at 75% average utilisation
- We feel above is a reasonable allowance for the base building system to achieve. Through the tenant fit out design process the aim is to provide additional CO_2 sensors for increased demand-controlled ventilation. We note however, this may not be realised unless additional volume control dampers or VAV boxes are provided to direct the airflow to where it is needed.

A.7.4.2 Heat Recovery

All heat recovery devices are assumed to be total heat recovery devices with 73% effectiveness. The devices are controlled as follows:

- Heating enabled when ambient is 2°K below relief air temperature and ambient is below desired supply air temperature setpoint.
- Cooling is enabled when ambient is 2°K above relief air temperature and also above 21°C or when ambient dewpoint is 1.8°K above relief air dewpoint and ambient dry bulb is also above 21°C.

No bypass of the heat recovery devices is assumed, the pressure drop of the heat recovery device is seen on the supply and relief air systems for all operational hours.

These assumptions are applied to the basement AHU and ground level heat recovery unit as well.

A.7.4.3 Supply Air Temperature

The DOAS systems limit the heating of the air supplied to satisfy the centre zone of greatest cooling demand. Given limitations in IES, one high internal load centre zone per system was selected as a proxy for all centre zones. This limit on heating for supply temperatures applies to both the heat recovery device and the air handler heating coil.

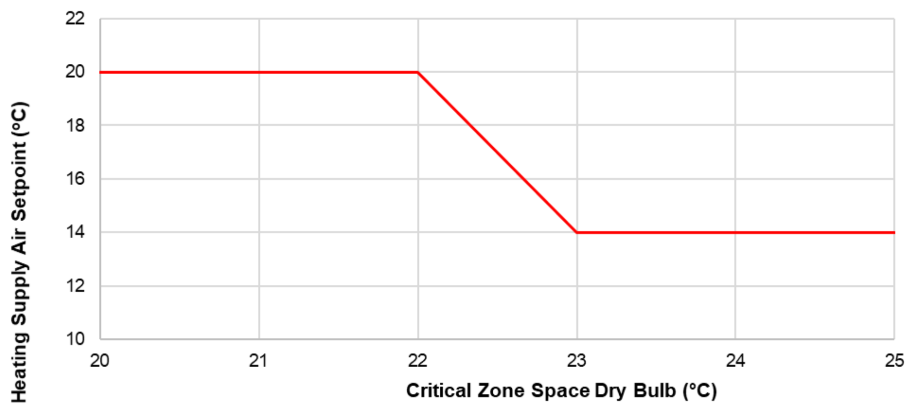


Figure 6 DOAS Supply Air Temperature Reset

In cooling mode, the heat recovery device and cooling coil cool the air down to a maximum of 21°C.

A.7.4.4 Supply Airflow

As air volumes vary in response to demand-controlled ventilation, the supply fans maintain a duct static pressure setpoint. That controls sequences allow for that setpoint to be adjusted in response to the floor branch VAV damper of greatest demand.

A.7.5 FCU Control

The fan coil units in the main office areas modulate heating and cooling over a 1°C proportional band with a 1°C deadband between the two as per the diagram below. Night setback heating also occurs to maintain any space at no less than 12°C. All FCUs are assumed to be constant flow.

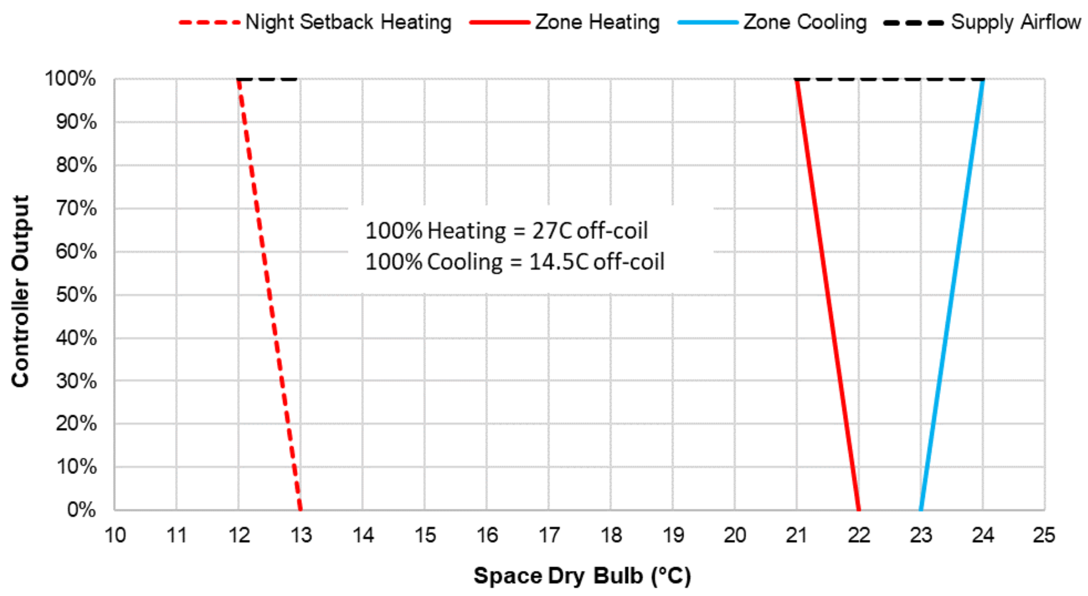


Figure 7 FCU Control

The FCUs in water closet areas operate similarly but with wider proportional bands of 21-22°C for heating and 25.5-26°C for cooling

A.7.6 Lobby

Consistent with the design intent the lobby operates on a 7am-6pm weekday schedule.

The full event mode economy cycle is not modelled due to complexities that would be introduced. With the revolving doors providing 575 L/s total infiltration during above operating hours, the heat recovery unit is allowed to lower its ventilation air volume from 400 L/s to 0 when ambient conditions are between 22-25°C (event mode). However, the operable louvres to allow the additional air to enter the space are not modelled, only the 575 L/s/ of outdoor air via infiltration is allowed not the full 2,000 L/s. We consider the model energy conservative as it would require more CHW cooling during these conditions than what would occur in reality.

The trench heating operates during night setback to maintain space temperatures at 12°C. The heaters are assumed to be 100% convective.

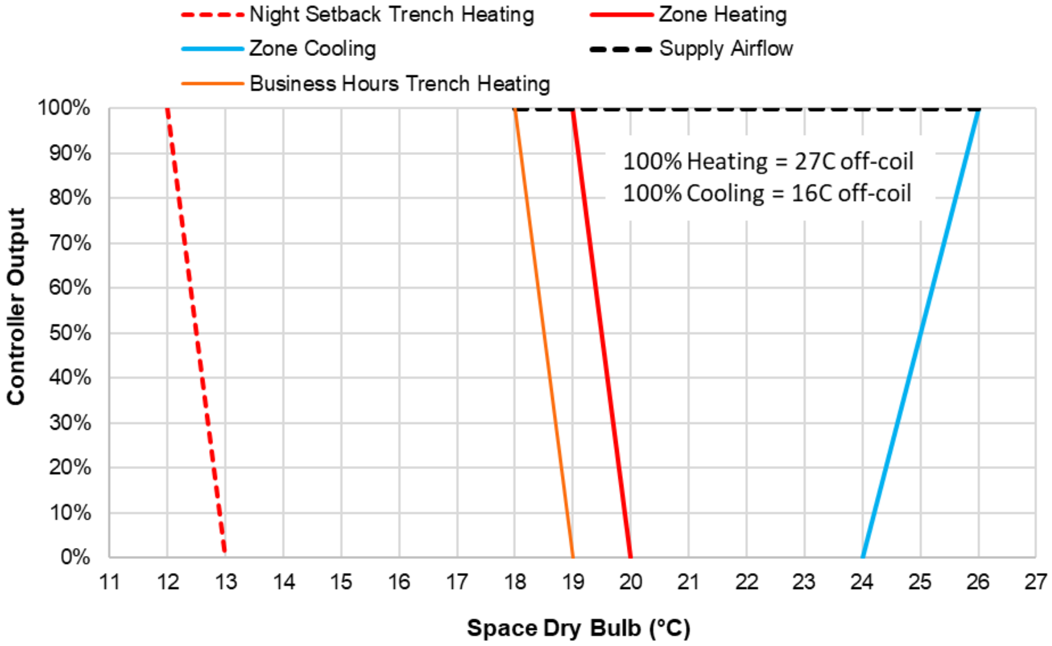


Figure 8 Lobby AHU Control

A.7.7 Basement

The basement AHU operates as constant volume 24/7 to ensure plant rooms remain ventilated and any elevated humidity in the basement is removed.

During the 6am-7pm working day period, the heat recovery device aims to warm the air to 20°C when cool outside and cool down to 21°C when warm outside. The active heating and cooling coils in the AHU condition to these supply temperatures when the heat recovery is insufficient.

Outside the 6am-7pm working day period, the system tempers up to 16°C when cool outside and down to 25°C when warm outside. The supply air temperature is allowed to float between 16-25°C during these hours.

The heating coil for the end of trip facilities controls to a minimum space temperature of 18°C with the coil modulating over a 1°C proportional band from 19-18°C.

A.8 Cooling Plant

Chilled Water is supplied from the district plant run by Engie. The district cooling plant consists of a combination of screw compression and absorption chillers using heat from the combined heat and power (CHP) system.

Chilled water is supplied through heat exchangers in the basement to supply the building, which is then passed through heat exchangers on each floor/retail unit to deliver chilled water to the tenants.

For the purposes of this energy estimation, the chilled water thermal load only needs to be estimated as a default energy weighting factor of 0.4 (COP=2.5) is applied to all district cooling thermal energy.

The thermal losses need to be assessed between the CHW coils and the utility thermal meters and pumping energy within the building needs to be accounted for.

A.8.1 Thermal Losses

Thermal losses have been allowed for via two components:

- Fixed UAΔT losses when the system is operating
- Pull down load when the plant starts up

A.8.1.1 Fixed UAΔT

Fixed UAΔT losses were estimated assuming:

- A rough take-off of pipe diameter and pipe length was completed using the schematics and floor layouts for the index runs. Similar runs were accounted for via multipliers for branches, runouts etc to arrive at an overall system loss.
- The AIRAH handbook was used to determine W/LM°K heat loss factors for metal pipe in still air for the nominated insulation thicknesses from the mechanical specification.
- As main pipe runs only were measured, the estimated UA is factored up by 35% to account for additional water volume and pipe surface area / losses from heat exchangers, valves, coils, plantroom pipework and other
- 50% of the final runout heat loss and 25% of the loss from the second to last branches were assumed to be recovered via return air to the FCUs.
- The combined impact is an estimated loss of 1.07% of loop capacity or 35.5 kWt including the on floor secondary pipework.

The take-off also suggested a duty point circulation time consistent with the 8 minutes suggested by the expansion tank system volume scheduled divided by the circulating pump duty flow.

Given the large portion of the anticipated loss being on floor to serve the office FCUs only, a differential UAΔT factor is applied where any load triggers an initial 3.3 kW (0.1%) loss and if any office area FCUs are requiring CHW, the additional 0.97% (32.2 kW) loss is added to this.

On average across the year these fixed losses amount to 7.1% of coil loads. This is substantial compared to our experience, but as an FCU system requires many lineal metres of small-bore pipework compared to central VAV or high temperature chilled water chilled beams, the higher losses are to be expected.

A.8.1.2 Pull Down Loads

When the system has not been operating for a period of time the loop temperatures are assumed to be warmer than setpoint.

The pull down load has been estimated assuming:

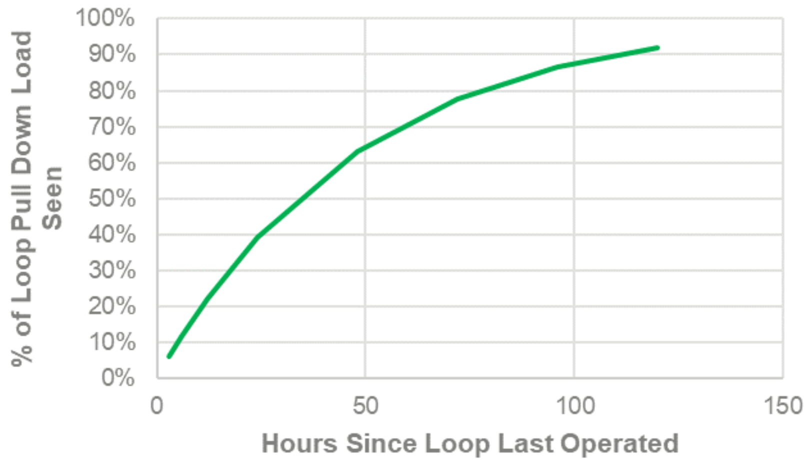
- Estimated system volume 63,444 kg based on duty flow of 132.44 L/s and an 8-minute system average circulation time (allowing for on floor CHW pipework). Note the expansion tank schedules a system volume of 66.7 kL
- Average surrounding environment of 22.5°C
- Mean loop operating temperature of 10.5°C which is the average of the design point flow and return temperatures.

The above assumptions suggest a full pull down load of 885 kWht. That full pull down load however will only occur if the plant has not operated for a long period of time.

Similar to the UAΔT split loss for office FCUs and the remainder of the system, 35% of the 885 kWht is assumed to be in the main pipework and risers and the remaining 65% in the on-floor pipework servicing the office FCUs. The pull down loads are thus triggered at different times and with different decay curves given that there are many long run hour cooling loads on the main loop for lift motor rooms, switch rooms, MER rooms etc

If the ambient environment is constant, the loss when the plant is not operating should be a classic decay curve as shown in figure below. We have assumed a 48-hour time constant which leads to 22% of the load being seen after 12 hours, 63% after 2 days and 92% after 5 days. The 48-hour time constant assumption leads to the pull down load after 13 hours of inactivity (6pm to 7am) being equivalent to 6.5 hrs of UAΔT losses which feels about right as UAΔT will reduce as temperatures drop and with reduced heat transfer at the pipe wall when the system is not circulating.

Figure 20: Decay Curve for Hydronic Loop Pull Down Loads



Overall, the pull down loads are simulated at 11.7% of the annual coil loads met.

A.8.2 Pumps

The table below illustrates parameters used within the analysis to estimate CHW pumping energy. The following assumptions have been made to ensure adequate pump sizes have been simulated:

- Pump flows have been established to align with the thermal capacity of the sum of on-floor heat exchangers. Design head pressures simulated are as scheduled.
- Tenant pumping flows have been established to align with the capacity of on-floor heat exchangers. Flow is modulated based on simulated tenant load.

Table 22 CHW pump characteristics

	High Load Primary Pumps (CHWP-B1.01/02)	Low Load Primary Pump (CHWP-B1.04)	On-Floor Secondary Pumps
Duty Flow (L/s)	69.5	13.9	Varies to meet FCU loads
Estimated Total System Pressure (kPa)	370	300	150
Assumed Constant Pressure (kPa)	150	150	100
ΔT (k)	4.5	4.5	4.5
Minimum Turndown (%)	20%	20%	20%
Wire to Water Efficiency (%)	66.2% (75% pump, 97% drive, 91% motor)	66.2% (75% pump, 97% drive, 91% motor)	53.6% (65% pump, 97% drive, 85% motor)
Design Point Power (kWe)	38.8	6.3	Varies

The following indicates the efficiency and pump control assumptions adopted:

- The primary pumps are staged up to satisfy flow requirements starting with low load, one high load, two high load with equal operating points, and all three pumps with equal operating points.
- We have assumed 75% of the design ΔT in operation to model a degree of high flow, low ΔT syndrome. This may not meet the utility supply agreements, but it is a conservative assumption to ensure energy coverage.
- Pump pressure is determined hourly by calculating a variable pressure component proportional to the square of the pump % flow. This is added to the constant pressure component and a constant wire-air efficiency is applied.
- Pumps are not allowed to operate below 20% flow which would be maintained via a bypass.

A.9 Heating Plant

HHW and DHW loads are supplied from the district plant run by Engie. The district heating plant uses a combination of fuel sources to meet the thermal load.

Low temperature heating hot water (LTHW) is supplied through heat exchangers in the basement to supply the building, which is then passed through heat exchangers on each floor/retail unit to deliver LTHW water to the tenants.

For the purposes of this energy estimation, the LTHW thermal load only needs to be estimated as a default energy weighting factor of 0.9 is applied to all district heating thermal energy.

The thermal losses need to be assessed between the LTHW coils and the utility thermal meters and pumping energy within the building needs to be accounted for.

A.9.1 Thermal Losses

Thermal losses have been allowed for via two components:

- Fixed UAΔT losses when the system is operating
- Warm up load when the plant starts up

A.9.1.1 Fixed UAΔT

Fixed UAΔT losses were estimated assuming:

- A rough take-off of pipe diameter and pipe length was completed using the schematics and floor layouts for the index runs. Similar runs were accounted for via multipliers for branches, runouts etc to arrive at an overall system loss.
- The AIRAH handbook was used to determine W/LM°K heat loss factors for metal pipe in still air for the nominated insulation thicknesses from the mechanical specification.
- As main pipe runs only were measured, the estimated UA is factored up by 35% to account for additional water volume and pipe surface area / losses from heat exchangers, valves, coils, plantroom pipework and other
- 50% of the final runout heat loss and 25% of the loss from the second to last branches were assumed to be recovered via return air to the FCUs.
- The combined impact is an estimated loss of 2.78% of loop capacity or 80 kWt including the on floor secondary pipework.

The take-off also suggested a lengthy duty point circulation times consistent well over 10-minutes thus we have used the 20 minutes suggested by the expansion tank system volume scheduled divided by the circulating pump duty flow.

Given the large portion of the anticipated loss being on floor to serve the office FCUs only, a differential UAΔT factor is applied where any load triggers an initial 6.3 kW (0.22%) loss and if any office area FCUs are requiring LTHW, the additional 2.56% (73.3 kW) loss is added to this.

On average across the year these fixed losses amount to 24.6% of coil loads. This is substantial compared to our experience, but as an FCU system requires many lineal metres of small-bore pipework compared to more central systems, the higher losses are to be expected.

A.9.1.2 Warm up Loads

When the system has not been operating for a period of time the loop temperatures are assumed to be lower than setpoint.

The warm up load has been estimated assuming:

- Estimated system volume 32,934 kg based on duty flow of 27.5 L/s and a 20-minute system average circulation time (allowing for on floor LTHW pipework). Note the expansion tank schedules a system volume of 36 kL
- Average surrounding environment of 22.5°C
- Mean loop operating temperature of 57.5°C which is the average of the design point flow and return temperatures.

The above assumptions suggest a full warm up load of 1,341 kWht. That full warm up load however will only occur if the plant has not operated for a long period of time.

Similar to the UA∆T split loss for office FCUs and the remainder of the system, 35% of the 1,341 kWht is assumed to be in the main pipework and risers and the remaining 65% in the on-floor pipework servicing the office FCUs. The warmup loads are thus triggered at different times and with different decay curves given that there are many long run hour heating loads on the main loop for basement ventilation etc

If the ambient environment is constant, the loss when the plant is not operating should be a classic decay curve as previously shown. We have assumed a 48-hour time constant which leads to 22% of the load being seen after 12 hours, 63% after 2 days and 92% after 5 days. The 48-hour time constant assumption leads to the pull down load after 13 hours of inactivity (6pm to 7am) being equivalent to 6.5 hrs of UA∆T losses which feels about right as UA∆T will reduce as temperatures drop and with reduced heat transfer at the pipe wall when the system is not circulating.

Overall, the warmup loads are simulated at 14% of the annual coil loads met.

A.9.2 Pumps

The table below illustrates parameters used within the analysis to estimate LTHW pumping energy. The following assumptions have been made to ensure adequate pump sizes have been simulated:

- Pump flows have been established to align with the thermal capacity of the sum of on-floor heat exchangers. Design head pressures simulated are as scheduled.
- Tenant pumping flows have been established to align with the capacity of on-floor heat exchangers. Flow is modulated based on simulated tenant load.

Table 23 LTHW pump characteristics

	High Load Primary Pumps (LTRHWP-B1.01/02)	Primary Pump Trench Heaters and Radiators (LTRHWP-B1.04)	On-Floor Secondary Pumps
Duty Flow (L/s)	14.5	0.32	Varies to meet FCU loads
Estimated Total System Pressure (kPa)	355	275	150
Assumed Constant Pressure (kPa)	150	150	100
ΔT (k)	18.8 (75% of 25)	18.8 (75% of 25)	18.8 (75% of 25)
Minimum Turndown (%)	20%	20%	20%
Wire to Water Efficiency (%)	66.2% (75% pump, 97% drive, 91% motor)	53.6% (65% pump, 97% drive, 85% motor)	53.6% (65% pump, 97% drive, 85% motor)
Design Point Power (kWe)	7.8	6.3	Varies

The following indicates the efficiency and pump control assumptions adopted:

- The primary pumps are staged up to satisfy flow requirements starting with low load, one high load, two high load with equal operating points, and all three pumps with equal operating points.
- We have assumed 75% of the design ΔT in operation to model a degree of high flow, low ΔT syndrome. This may not meet the utility supply agreements, but it is a conservative assumption to ensure energy coverage.
- Pump pressure is determined hourly by calculating a variable pressure component proportional to the square of the pump % flow. This is added to the constant pressure component and a constant wire-air efficiency is applied.
- Pumps are not allowed to operate below 20% flow which would be maintained via a bypass.

A.10 Miscellaneous Fans

The remaining mechanical equipment energy use that has not already been accounted for within the building is primarily limited to miscellaneous fans. The airflows and pressures are aligned to the axial fan equipment schedules. No specific fan power limit is specified on these fans, efficiency assumptions have been determined based on our experience.

The full load equivalent (FLE) run hour assumptions and total energy consumption for each fan type are shown below.

It is unclear whether the Kitchen Exhaust fans are base building or tenant energy. The landlord provides the spatial provision for a tenant to install a KE system, the tenant installs that system not the landlord.

Table 24 Miscellaneous Fan energy

Fan No.	Area Served	No. Off	Design Flow (L/s)	External Static Pressure (Pa)	Total Pressure (Pa)	Fan Shaft Power (kW)	Fan Total Efficiency	Drive + Motor Efficiency	Total Wire-Air Efficiency	Electrical Power (kWe)	Annual Operation (hrs/pa)	Operational Profile	Annual Energy Use (kWh/pa)
GEF-B1.01	Cycle store extract fan	1	2,705	290	345	1.44	65%	85%	55%	1.69	4,028	Cycle Store	6,802
GEF-00.01	Oil transfer room extract fan	1	235	150	154	0.06	60%	60%	36%	0.10	8,760	Continuous	878
GEF-00.02	BOH extract fan	1	60	65	66	0.01	60%	60%	36%	0.01	3,168	Business Hours Extended	35
GEF-00.03	Loading bay	1	2,160	250	275	0.92	65%	85%	55%	1.08	3,168	Business Hours Extended	3,411
GEF-00.04	Loading bay - Refuse	1	2,115	250	274	0.89	65%	85%	55%	1.05	8,760	Continuous	9,201
KEF-RF.01	North office tenant kitchen exhaust fan	1	3,500	300	312	1.82	60%	90%	54%	2.02	600	Commercial Kitchen	1,213
KEF-RF.02	South office tenant kitchen exhaust fan	1	1,800	300	308	0.92	60%	85%	51%	1.09	600	Commercial Kitchen	652
OAF-00.01	Sprinkler pump room supply air fan	1	300	250	256	0.15	50%	60%	30%	0.26	10	Fire	3
OAF-00.02	Wet mains pump room supply air fan	1	250	250	254	0.13	50%	60%	30%	0.21	10	Fire	2
OAF-00.03	Dock Manager's Office Outdoor air fan	1	30	185	185	0.01	50%	60%	30%	0.02	2,540	Business Hours	47
SAF-01.01	Level 1 FM office	1	95	185	187	0.04	50%	60%	30%	0.06	2,540	Business Hours	151
SAF-TYPE 01	SER general extract fan	7	85	65	67	0.01	50%	60%	30%	0.02	8,760	Continuous	1,161
SDPF-RF.01	High rise smoke depressurisation Colt fan	1	4,060	390	414	2.80	60%	90%	54%	3.12	10	Fire	31
SEF-B1.01	Basement smoke clearance system	1	2,020	300	310	1.04	60%	85%	51%	1.23	10	Fire	12
SMF-B1.01	Basement smoke clearance Make-up Air system	1	2,020	300	310	1.04	60%	85%	51%	1.23	10	Fire	12
TEF-RF.01	Core toilet exhaust fan north	1	8,270	350	451	5.74	65%	90%	59%	6.38	3,168	Business Hours Extended	20,216
											Total		**43,826**

Table 25 Miscellaneous Fan Operational Profiles

Operating Hours per Year		Comments
Cycle Store	4028	100% duty 12 hours per working
Business Hours	2540	8am to 6pm Weekdays
Business Hours Extended	3168	7am to 7pm Weekdays + 3 hrs on Saturdays
Continuous	8760	Continuous
8am to 6pm – 7 days	3640	8am to 6pm all week
Fire	10	10hours per year (testing only)
Commercial Kitchen	600	4hours, 3 days a week

A.11Miscellaneous Fan Coil Units

The energy use for other miscellaneous mechanical equipment is estimated in the table below. Note the column indicating where thermal or fan energy use is modelled within IES or in the pumps spreadsheet.

Table 26 Miscellaneous Fan Coil Units

Assumed Average Internal Pressure Drop (Pa)	90	Coils + Filter
Assumed Average discharge Velocity (M/s)	7.0	

Unit	Service / Area		Where is Equipment Estimated	Qty	Supply Air Flow (l/s)	Total Cooling (kWr)	Sensible Cooling (kWr)	Heating Capacity (kWt)	Specific Fan Power (W / L/s)	Estimated External Pressure (Pa)	Estimated Total Pressure (Pa)	Estimated Fan Power input (kWe)	Fan Run Hours (Full Load Equivalent hrs/pa)	Average Cooling Operating Point (%)	Average Heating Operating Point (%)	Cooling FLE Hours	Heating FLE Hours	Fan Energy Use (kWh/pa)	Chilled Water Load (kWht/pa)	HHW Load (kWht/pa)
FCU-00.01	Reception - Breakout Area Adjacent to Desk	FCU	Fan & Coils Here	1	151	1.9	1.4	1.11	0.2	30	149	0.03	3,012	20%	29%	602	870	101	1,157	966
FCU-00.02	Reception - Desk	FCU		1	151	1.9	1.4	1.11	0.2	30	149	0.03	3,012	20%	29%	602	870	101	1,157	966
FCU-00.03	Security Room	FCU		1	233	2.5	1.9	1.00	0.2	30	149	0.05	8,760	20%	10%	1,752	870	452	4,292	870
FCU-00.04	Dock Managers Room	FCU		1	238	2.5	2.0	1.25	0.2	30	149	0.05	3,012	20%	29%	602	870	159	1,506	1,088
FCU-00.05	Active Lobby - Garden Stair	FCU		1	328	3.4	2.8	1.98	0.2	30	149	0.07	3,012	20%	29%	602	870	219	2,075	1,723
FCU-00.06	Active Lobby - Garden Stair	FCU		1	328	3.4	2.8	1.98	0.2	30	149	0.07	3,012	20%	29%	602	870	219	2,075	1,723
FCU-01.01	Facilities Management Office	FCU		1	274	2.9	2.5	1.37	0.2	30	149	0.06	3,012	20%	29%	602	870	183	1,735	1,192
FCU-01.02	Facilities Management Welfare	FCU		1	86	0.9	0.6	0.35	0.2	30	149	0.02	3,012	20%	29%	602	870	57	542	305
FCU-12.01	Low Rise Lift Overrun	FCU	Fans only, Cooling Elsewhere	1	620	9.8	9.8	-	0.2	30	149	0.14	2,108			-	-	289	-	-
FCU-12.02	Low Rise Lift Overrun	FCU		1	620	9.8	9.8	-	0.2	30	149	0.14	2,108			-	-	289	-	-
FCU-RF.01	Roof Level - High Rise Lift Motor Room	FCU		1	613	9.7	9.5	-	0.2	30	149	0.14	2,108			-	-	286	-	-
FCU-RF.02	Roof Level - High Rise Lift Motor Room	FCU		1	613	9.7	9.5	-	0.2	30	149	0.14	2,108			-	-	286	-	-
FCU-RF.03	Roof Level - High Rise Lift Motor Room	FCU		1	613	9.7	9.5	-	0.2	30	149	0.14	2,108			-	-	286	-	-
FCU-RF.04	Roof Level - High Rise Lift Motor Room	FCU		1	613	9.7	9.5	-	0.2	30	149	0.14	2,108			-	-	286	-	-
CCU-B1.01	CRAC Basement Level Switch Room	CRAC		1	3,300	36.5	36.0	-		50	169	0.83	2,683			-	-	2,222	-	-
CCU-B1.02	CRAC Basement Level MER	CRAC		1	1,650	15.5	15.0	-		50	169	0.41	2,683			-	-	1,111	-	-
FCU-Type01	Typical Core North WC	FCU	Fans & Coils in IES Model	21	124	0.7	0.7	1.30	0.2							-	-	-	-	-
FCU-Type02	Typical Core South WC	FCU		21	162	0.9	0.9	1.90	0.2							-	-	-	-	-
FCU-21.01	Level 21 WC North	FCU		1												-	-	-	-	-
FCU-21.02	Level 21 WC South	FCU		1												-	-	-	-	-
																	Total (kWh)	**6,545**	**14,539**	**8,831**
																	Total (MWh)	**6.55**	**14.54**	**8.83**

A.12 Base Building Lighting

Estimates for base building lighting energy use have been established from the lighting drawings and applying operational profiles across the various control circuits. Control group run hours have been established in line with 2019 discussions and previous project experience.

House lighting is LED throughout, controlled via motion sensing. As a result, no house lighting outside of stair areas is proposed to have 24/7 luminaire circuits. Stair lighting is controlled on motion sensing with lights operating at a minimum 10% output and increasing to 100% output when inter-floor stair traffic brings lights on locally.

Table 27 Base Building lighting energy calculations

Control Groups	Description	Full Load Equivalent (hrs/pa)	Notes	Connected Load (kWe)	Energy (MWh/yr)
A	24/7 Lighting	8,760	100% on 24/7	2.7	23.4
B	Emergency Lighting	0	0% 24/7	0.2	0
C	Exterior	2,190	Dusk till midnight 7 days week - assume 6 hrs/day average	1.1	2.3
T	Toilets	3,048	7am-7pm M-F, 50% area at 4 hrs on Sat, off Sun	18.0	54.9
E	Lift Lobby / BB Corridor	4,476	14hr/WD at 100%, 4hr/WE at 100%, 10% at all other times	11.4	51.2
F	Ground Floor Lobby	6,412	16 hrs/day (6am-10pm) M-F at 100%, at 50% all other times	4.0	25.9
G	Plant Areas	254	1hr/WD	0.6	0.1
H	BOH Areas	254	1hr/WD	13.4	3.4
I	Stairs/Egress	2,924	12hr/WD at 75%, 4hr/WE at 25%, 10% at all other times	12.5	36.4
Total					**197.7**

A.13 Vertical Transportation

In line with the Guide to Design for Performance we have used the simplified Bannister empirical lift energy model assuming:

- All lifts are Variable Voltage Variable Frequency (VVVF) drives with regeneration in line with the lift specification
- A total building net internal area served of 32,589 m^2
- 5 low rise lifts across 13 floors
- 5 high rise lifts across 22 floors (including bypassed floors)

The default formula in the Guide to Design for Performance suggests 5.251 kWh/m^2 pa of lift system energy use.

The benchmark data on which the model is based are understood to include all lift system energy use including the packaged units typically used to cool lift motor room drives and control gear. For this reason, a typical COP for packaged equipment of 3.25 is assumed to determine a lift drive and control gear electricity consumption benchmark of 4.016 kWh/m^2 pa. 95% of this electricity use is then assumed to appear as a LMR cooling load on the CHW system. The fan energy use of the FCUs within the LMRs is included in the miscellaneous fans table and is in addition to the above allowances.

This level of lift system energy use is consistent with our experience in mid-rise type office buildings.

A.14 Domestic Hot Water

We have used the 4 L/person/working day of service hot water (DHW) demand in line with Section 8.4 of the Guide to Design for Performance. In recent office building projects we have measured typical floor amenity DHW flows to be just under 1 L/person/day and End of trip DHW flows have been estimated at 1.8 L/person/day diversified. We consider the 4 L/person/day benchmark to be slightly conservative. Beyond this average flow rate, we have assumed:

- We have assumed an average building population of 14.3 m^2/person (10 m^2/work point @ 70% average utilisation) which is denser than the assumption made in the IES model.
- Average mains water make-up temperature of 11°C based on London's average annual temperature in the TRY file being 11.4°C.
- Average flow temperature to fixtures of 60°C.
- With the system operational 24/7 we have assumed the 7 kW of standing losses specified in the public health specification / schedules occurs throughout the year.
- The 7 kW electric boost heater operates at times when there is no DHW demand. This is assumed to be outside the 8am-6pm weekday period. Within business hours the thermal losses are met by the LTHW supply.

The above assumptions result in an estimated DHW demand of 135,423 kWh/pa with total losses of 61,320 kWh split into 43,050 kWh of electricity outside business hours and 18,270 kWh of thermal load during business hours. These losses represent 45% thermal loss across the hot water demand on average.

The pump energy use associated with DHW systems is covered under the hydraulic pump allowance.

A.15House Power

A.15.1 Diesel generator sump heaters

In a colder climate, generator sump heater energy use could be quite significant. The following assumptions have been made to provide what we feel is a conservative estimate of sump heater energy use:

- Effective surface area for heat exchange of 2 m^2 between oil sump and surrounding plantroom for the base building generator.
- 8.3 W/m^2°K heat transfer coefficient allowing for convective and radiative heat transfer

- Oil sump temperature of 55°C
- Surrounding environment temperature qual to the London TRY weather file dry bulb temperature. In practice the plantroom will provide some insulating effects.

The estimated energy use given above is 6,346 kWh/pa. Future tenant generator ancillary / sump energy use is assumed to be suppled from a tenant supply.

A.15.2 Closed Cavity Façade (CCF) Compressed Air and Drying System

The dry air system supplied to the closed cavity façade consists of an air drier (air cooled chiller) and compressed air system to pump the dry air to the CCF façade modules. The energy use estimate has been based on the follow capacity data supplied by Scheldebouw:

- 250 m^3/hr design airflow
- 150 mbar (1.5 kPa) gauge pressure
- 10 kWr chiller capacity to dehumidify the air

With that capacity data we have made the following assumptions to estimate energy use:

- Average chiller COP of 1.5 allowing for poor part load performance
- Total compressor efficiency of 50%
- Average ambient dewpoint of 8°C (6.68 g/kg) from London weather data and an assumed after cooler dewpoint of -15°C (1.02 g/kg). Combined with airflow this leads to 1,685 g/hr of dehumidification load
- It is assumed that the chiller cools the air to -15°C which we believe is conservative as the system would aim to reheat that air to have warm dry air supplied to the façade.
- Assumed average diversity for compressor and chiller of 70%

From above assumptions we estimate the system could use up to 15,193 kWh/pa of electricity. The majority of this is in the sensible cooling of the air which may be overstated if the system reheats the air to reduce head pressure on the chiller compressor post dehumidification.

A.15.3 Trace Heating

Fire sprinkler and potable or Cat 5 water supply pipework exposed to ambient is heat traced to maintain 4°C pipe surface temperature. This pipework is insulated to limit the heat trace. We have not taken a full take-off but have made the following assumptions to estimate this end use:

- 200m total of exposed pipework across all systems - this is a guess.
- Average 25mm bore pipe with 25mm insulation
- A heat loss from the pipework in still air of 0.183 W/LM°K from the AIRAH handbook
- 2,065 degree hours below 4°C determined from the London TRY weather file

From above the heat trace is estimated to consume 76 kWh/pa.

A.15.4 Greywater

Limited information is available on the likely energy use of the greywater treatment system. We have estimated energy use based on past project experience of water flows and recycled water system energy use. The following assumptions have been made:

- Based on modern Australian office building water benchmarking we estimate the greywater flows to be:
  - 0.0395 kL/m^2 pa of flow from basins
  - 0.0339 kL/m^2 pa of flow from end of trip showers which is factored up to assume 6% of office workers on average shower at work each day relative to the 4-4.5% we have estimated is typical of modern office building EoT utilisation.
  - Above measured water use we believe is coincident with an average building population of 15 m^2/person
  - Above benchmarks lead to an estimated greywater flow of 2,414 kL/pa or 9.6 kL/working day on average for the building
  - The average daily flow of 9.6 kL/working day compares well to the plant capacity of 16 kL/day
- In lieu of better information, we have assumed 3 kWh/kL specific greywater system energy use based on an upper end of past project experience. This level of energy use is relatively high and we believe comfortably cover a treatment process that does not have reverse osmosis.

Based on above assumptions we estimate 7,242 kWh/pa of greywater system energy use. The pressure pumps for the supply of the recycled water are accounted for within the hydraulic pumps.

A.15.5 Main Equipment Room Cooling

Electricity use within main equipment rooms is not well understood in our industry. To estimate this end use we have assumed:

- 50% average business hours diversity on the cooling capacity of 15.5 kWr with 10% assumed outside business hours.
- That heat load is assumed to be generated solely by the base building electricity consumed in the room.
- The above assumptions result in 0.91 kWh/m^2 pa of electricity use and CHW heat load.

A.15.6 Other

An additional 1 kWh/m^2 pa allowance has been included to account for any plug loads such as cleaning equipment and vending machines or for unaccounted systems like fire information panels.

A.16 Hydraulic Pumps

The public health services hydraulic pump energy use has been estimated as follows.

Hot Water Service (DHW) pumps:

- From the public health specification and equipment schedules a total of 1.9 L/s x 2 = 3.8 L/s of total service hot water flow is specified across the four zones
- 20m operating head pressure
- Assumed 70% diversity on above

- Average wire-water efficiency of 45%
- Pumps assumed to circulate 24/7
- 7,112 kWh/pa of electricity use is estimated from above assumptions

Potable Water, Grey Water and Category 5 Water supply:

- Water demand for modern Australian office building of 0.509 kL/m^2 pa excluding cooling towers.
- We have assumed this volume of water needs to be boosted / lifted the height of the building of 89.9m (882 kPa)
- The operating head pressures for the booster pumps have an average pressure of 1,100 kPa so we have used that as a more conservative estimate of the average pressure to boost all water.
- 50% wire-water efficiency
- 10,208 kWh/pa of electricity use is estimated from above assumptions

A.17 Switchboard & Reticulation Losses

2% of all tower electricity use is assumed to be lost through the reticulation between the main switchboards and equipment including distribution boards. This value is arrived at allowing for a maximum 5% voltage drop and reducing this value to an average operational loss based on losses generally following an I2R loss. Thus 2% loss relates to an average design current of 63% which based on measured buildings is a conservative assumption.

Note this loss does not factor in transformer losses and assumes low voltage utility meters in line with NABERS.

The switch room is located within the building surrounded by tempered and unconditioned spaces. Any heat build-up will thus need to be removed via the CRAC units provided. The normal duty CHW CRAC unit has a total capacity of 36 kWr.

While there may be times of peak demand where the capacity is approached, one average highly diversified loads will occur. If we assume 1% of the building's electricity use is lost as heat in the switch room that would lead to a heat load of 1 kWh/m^2 assuming tenant and base building electricity use is approximately 100 kWh/m^2 pa.

To match this figure, we have assumed 30% average diversified cooling load during business hours and 3% outside those hours to arrive at an annual CRAC cooling load of 1.07 kWh/m^2 pa.

Contact us

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