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FUTURE PROOFING RESIDENTIAL DEVELOPMENT TO CLIMATE CHANGE

STAGE 1 REPORT

JANUARY 2021

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Future Proofing Residential Development to Climate Change
Stage 1 Report

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GLOSSARY

Baseline Year / Baseline Year (2020)	In the context of this report, references to Baseline Year relate to the BASIX and NatHERS software tools as approved for regulatory use in 2020.
BASIX	NSW planning legislation in the State Environmental Planning Policy (Building Sustainability Index: BASIX) 2004, known as the BASIX SEPP, enabled under the EP&A Regulation 2000, and implemented through the BASIX online tool https://www.planningportal.nsw.gov.au/basix
COAG	Council Of Australian Governments
DCP	Development Control Plan
DGU	Double Glazed Unit
DPIE	NSW Department of Planning, Industry and Environment
FR5	Common abbreviation for the NatHERS-approved FirstRate5 modelling software.
IES VE	Integrated Environmental Solutions (IES) is a software vendor. The VE software is an in-depth suite of integrated analysis tools for the design and retrofit of buildings.
$kgCO_2$-e	Kilograms of CO_2 equivalent. A typical measure of Greenhouse Gas Emissions that accounts for CO_2, the benchmark greenhouse gas, as well as the many other greenhouse gases that can contribute to global warming.
LEP	Local Environment Plan
MJ/m^2	Megajoules per square metre – measure of load or energy consumption per unit area of a dwelling
MUD	Multi-Unit Development. A typical term used to describe larger apartment buildings
NARCLiM	"NSW and ACT Regional Climate Modelling"
NatHERS	"Nationwide House Energy Rating Scheme" https://www.nathers.gov.au/ Accredited modelling performed in accordance with the NatHERS protocol/technical notes is used to determine heating and cooling loads for a given location, associated with maintaining acceptable dwelling thermal comfort through use of air conditioning.
NCC	National Construction Code is a performance-based code that sets the minimum requirements in relation structure, fire safety, access and egress, accessibility, health and amenity, and sustainability.
SEPP	State Environmental Planning Policy. These legislated policies are environmental planning instruments that deal with matters of State or Regional environmental planning significance.
SGU	Single Glazed Unit
SHGC	Solar Heat Gain Coefficient – this is the measure of glass or a window system's ability to transmit or limit incoming solar radiation to the interior of a building. Lower SHGC results in less solar heat gain to the interior space. Expressed as a decimal fraction between 0 and 1. Being a coefficient, SHGC is unitless.

Thermal Comfort	A measure of the internal thermal conditions of a building considered to be representative of responses for the majority of occupants. BASIX thermal comfort assessment considers the heating and cooling loads on a dwelling against benchmark thresholds for each NatHERS climate zone considered to result in acceptably comfortable conditions. Buildings with effective passive design features will require less energy for air conditioning to achieve thermal comfort than buildings that do not consider passive design elements
Thermal Performance	An indicator of a material or construction’s properties in terms of heat transfer / thermal mass / solar admittance. For example, an insulating material achieves good thermal performance by limiting heat transfer effectively.
U-value	This is a measure of the thermal conductivity of a construction, typically used for describing the thermal properties of glass or window systems. Lower U-value represents less thermal conductivity and therefore better insulation performance. Standard metric units for U-value are $W/m^2 \cdot K$
VVVF motor	Variable voltage variable frequency motor – a higher efficiency option for lift motors

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EXECUTIVE SUMMARY

With global temperatures projected to rise by 2.5°C in the next century, residential buildings and homes will need to become more resilient to withstand hotter temperatures, drier climates and more extreme weather events. This anticipated change in climate is a key consideration for all levels of government, and commitments are being made at local and international levels to address the impacts of climate change. This includes the need to better understand climate change and its impacts on current building design practices and regulations.

This study is one of a growing number being carried out to help inform improved building design policies, by taking into account predicted future climate scenarios. **The homes we build today need to be designed to be energy and water efficient, thermally comfortable, safe to live in and inexpensive to cool, to ensure that everyone has equitable access to a cool home as our climate warms.** In addition, residential buildings can play a significant role in addressing rising temperatures by assisting local, state and federal governments to achieve climate change mitigation targets and commitments.

The aim of the *Future Proofing Residential Development to Climate Change* research project is to model the performance of BASIX compliant building designs against future climate projections for the Eastern Sydney region (Randwick, Woollahra and Waverley councils), to determine the effects of climate change on building thermal performance, energy consumption, greenhouse gas emissions and water demand.

The findings of this study are expected to identify actions to enhance the climate resilience of residential housing within the Eastern Beaches region, and that may have applications within other jurisdictions. These actions will complement existing regulatory controls with council-led initiatives to improve indoor thermal comfort, reduce energy consumption, greenhouse emissions and potable water use. It is hoped that these results will allow for significant improvement in the design of buildings across NSW.

1.1 METHODOLOGY, MODELLING AND ANALYSIS

As part of this study, modelling and analysis was undertaken for five different residential building types, as shown in Table ES.1 below. Buildings representative of typical Eastern Suburbs housing were chosen, where they were compliant with current NSW residential development sustainability requirements – known as BASIX commitments.

Table ES.1 BASIX sample building types assessed

Building Types				
Detached	**Attached (duplex/semi/townhouse)**	**Low-rise (up to three storeys)**	**Mid-rise (four to five storeys)**	**High-rise (six storeys & above)**

The modelling reviewed the performance of each building type against three criteria:

- Thermal comfort of the dwelling i.e. estimated heating and cooling loads
- Energy consumption and greenhouse emissions
- Water consumption

Each building type was then assessed for these criteria under three different climate scenarios:

- Present day 2020 (to serve as a Baseline Year)
- Near future change 2030 (average 2020 – 2039)

– Far future change 2070 (average 2060 – 2079)

The analysis used existing modelling tools to assess the performance of these building types under each climate scenario. These included the Nationwide House Energy Rating Scheme (NatHERS) accredited software and IES VE software for thermal comfort, and the Building Sustainability Index (BASIX) online tool for energy and water consumption.

1.2 RESULTS

1.2.1 THERMAL COMFORT PERFORMANCE RESULTS

The modelling results indicate that as the climate warms in 2030 and 2070, dwellings in the Eastern Suburbs will have negligible heating needs. However, energy demand for cooling in summer is predicted to dramatically increase. **All dwelling types tested failed the current BASIX Thermal Comfort requirements for cooling in 2030 and 2070**.

The key results are listed below:

- Under the 2030 and 2070 future climate scenarios, there was a distinct shift away from evenly-matched heating and cooling loads in the Baseline Year towards greatly increased cooling loads and substantially reduced heating loads.
- In 2030, cooling loads increased by 70% on average above the Baseline Year. The heating loads dropped significantly, reducing to 39% of the Baseline Year loads on average.
  Combined loads remained on par with the Baseline Year.
- In 2070, cooling loads increased by 308% on average above the Baseline Year.
  Average heating loads dropped to 19% of Baseline Year loads.
  Combined loads drastically increased, averaging 83% above the Baseline Year.
- The significant increase in cooling loads means that overall air-conditioning energy demand for maintaining comfort in warm periods will be much higher compared to the Baseline Year.

The dominant feature of the future climate for thermal comfort is higher temperatures for more of the year in the Eastern Sydney locality, with some extra and hotter extreme heat days. The principles of climate responsive design would dictate that, in response to these results, residential building designs should be accounting for hot climate conditions to address primarily cooling comfort requirements most of the time.

The buildings most affected by heat were the Attached, Detached and Low-rise dwellings. The least impacted dwelling type was High-rise building, benefitting from design factors such as a higher proportion of shared walls, floors and ceilings between dwellings compared to other building types as well as extra height contributing to better natural ventilation opportunity for upper level dwellings. Despite this, the High-rise building exceeded the current acceptable cooling load by a factor of about 250%.

These results show it is possible the dwellings approved for construction now will be unsuitable for occupation by 2070, without extremely high levels of mechanical cooling to maintain comfortable, safe and liveable conditions.

1.2.2 ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS RESULTS

Modelling results from BASIX show overall energy consumption was only slightly impacted by a warming climate. The small impact is explained by the increased energy needed for cooling homes being offset by reduced energy to heat homes in cooler months, as well as the makeup of energy scoring that accounts for multiple energy use sources in a home apart from air-conditioning that don’t change in response to increased temperatures.

In the 2030 scenario, all building types, except the Attached dwelling type achieved a pass rate according to BASIX Energy requirements.

However, in the 2070 scenario, increases in energy demands (due to greatly increased cooling energy needs) caused four of the five building types to fail BASIX. The High-rise building passed due to economies of scale in the larger number of units in the building compared to other types. Common area impacts were spread over a greater number of units, and the greater ratio of shared walls to external surfaces for each unit helped to manage the thermal comfort loads and demands for air conditioning energy. Inclusion of renewable energy in the baseline case further assisted the High-rise building to pass BASIX Energy requirements when tested under the 2070 climate scenario.

1.2.3 WATER USE RESULTS

The climate data for 2030 indicates lower rainfall than 2070, and this is reflected in the modelling results from this study. All building types failed the BASIX Water target when modelled in the 2030 climate scenario.

The worst performing dwelling type was the Detached house, with significant landscaping and the presence of a swimming pool the likely contributors to low performance. Additionally, the use of rainwater tanks connected for internal uses do not score as well in 2030 due to lower rainfall levels. By comparison, High-rise multi-unit buildings with a lower landscaping area per dwelling, only scored one point below a passing score in the 2030 scenario.

Even though 2070 is predicted to be potentially less dry than 2030, 2070 is still drier than the current climate. Therefore with the exception of the High-rise building, all building types failed to meet the BASIX Water target in the 2070 scenario.

1.3 KEY FINDINGS

1.3.1 THERMAL COMFORT AND ENERGY CONSUMPTION

The BASIX thermal comfort and energy modelling results from this study indicate that NSW will need to plan for greater mechanical cooling demands in the future, both from a peak demand management perspective and to reduce greenhouse gas emissions. In addition, NSW will need to consider equitable access to cooling, to ensure continued affordability and the potential grid implications.

It is recommended that:

- The climate files used in the NatHERS software are updated to ensure dwellings are designed to withstand future conditions.
- Design modifications are investigated for different building types to guide the Thermal Comfort policy setting in BASIX under future climate scenarios.
- The Thermal Comfort Heating and cooling load balance in BASIX is reviewed, in particular the cooling cap.
- The BASIX heating and cooling calculations for Energy scoring are reviewed.
- A review of BASIX Energy scoring targets and provisions for multi-unit developments be undertaken, so that the lower target scores for Energy these attract reflect the inherent efficiency advantages for dwellings in higher density developments while encouraging improved efficiency measures and peak demand reductions from both common areas and individual dwellings.

1.3.2 WATER

NSW will need to plan for greater water demand from the residential sector due to the projected warmer climate. Given the uncertainties in rainfall under future climate scenarios, rainwater tanks may not be as reliable to reach the BASIX Water target in future. Alternative water supplies may play a role in meeting the Water targets, with consideration of treated storm water and recycled water reticulation suggested as two possible solutions. Landscaping calculations for water consumption may also need to be revised.

It is recommended that:

- The BASIX tool is updated with climate data that more accurately represents the near-term and longer-term future drier climatic conditions that these buildings and their occupants will need to withstand.

- The BASIX calculations are reviewed in relation to outdoor water consumption (particularly the landscaped irrigation assumptions) given the predicted shifts in rainfall and evaporation for NSW.
- Once the climate data is updated and the calculations are reviewed, further testing of different building examples is completed to ensure that all building types can meet the BASIX Water targets.

1.4 POLICY RECOMMENDATIONS

A range of recommendations have been put forward as a result of the findings from this study to support residential preparedness and resilience in the face of a changing climate. These recommendations have been summarised below.

RECOMMENDATION 1: IMPROVEMENT TO CURRENT REGULATORY TOOLS i.e. BASIX and NatHERS

- Improve NatHERS tool with updated climate data, ideally a future climate file, for example 2030, to ensure buildings are built to withstand future climate conditions.
- Improve BASIX tool with updated climate data, for example the 2030 climate scenario, and review calculations.
- Review BASIX policy considering NSW Government policy on net zero carbon emissions e.g. all electric homes.
- Review BASIX targets e.g. strengthen BASIX Energy target for multi-unit buildings and review BASIX Water target for Detached/Attached dwellings. Investigate if targets can be adjusted spatially to reflect different climates.
- Identify design modifications for different building types to guide the Thermal Comfort policy setting in BASIX under future climate scenarios.
- Establish a monitoring and evaluation protocol that ensures that:
  - BASIX is reviewed and adapted every three years in line with National Construction Code (NCC) updates
  - Utilities are required to monitor the energy and/or water consumption of BASIX dwellings to support robust data in BASIX
  - The BASIX methodology is published to allow for peer review
- Ensure that revenue from the BASIX State Environmental Planning Policy (SEPP) is utilised for tool maintenance and enhancement

RECOMMENDATION 2: LOCAL GOVERNMENT CONSIDERS A NUMBER OF OPPORTUNITIES

- Prepare Development Control Plan / Local Environment Plan (DCP/LEP) clauses to strengthen non-BASIX sustainability initiatives e.g. transport, urban heat island effect, rainwater tanks for pools < 40kL.
- Improve BASIX and NatHERS compliance through educational videos for built environment professionals.
- Provide education to homeowners and tenants around water security e.g. rainwater tank maintenance, raingardens.
- Provide education to existing homeowners and tenants around keeping your home cool e.g. external shading, shading with landscaping, resilient species etc.

RECOMMENDATION 3: NSW GOVERNMENT CONSIDERS RESPONSE TO EMERGING CHALLENGES

- Peak electricity demand challenges for existing housing stock as the climate warms.
- Greenhouse gas impacts of increased use of air conditioning/mechanical cooling for all homes
- For greater water demand from the residential sector in a warmer climate, and the provision of alternative water supply e.g. recycled water to all Sydney residences.

2 PROJECT OBJECTIVES

2.1 BACKGROUND

With the ten hottest years globally being recorded since the turn of the millennium (NOAA National Centers for Environmental Information, 2020), it is evident now more than ever that measures must be taken to prepare for a hotter climate. The residential building industry is no exception to this, with a global temperature rise of 2.5ºC forecasted for the next century. Homes will need to be more resilient to not only hotter temperatures, but drier climates and more extreme weather. With good design practices, homes can be energy and water efficient, have low greenhouse footprints, and be safe and comfortable for occupants.

Residential buildings will also play a large role in Local, State and Federal Government policies addressing climate change. Existing commitments to reducing climate impacts include the NSW Government's target for net zero emissions by 2050, and the Trajectory for Low Energy Buildings, a COAG-developed pathway towards zero carbon buildings. Carbon offsetting may also be pursued with home solar generation, which aligns with the National Energy Productivity Plan to improve energy productivity by 40 per cent by 2030. By ensuring that building controls encourage good building design, NSW residential developments can increase their preparedness for future conditions while reducing their greenhouse gas emissions and water footprint.

2.2 AIMS

The aim of this *Future Proofing Residential Development to Climate Change* research project is to model the performance of BASIX-compliant building designs against future climate projections for the Eastern Beaches region (Randwick, Woollahra and Waverley Councils), to determine the effects of climate change on building thermal performance, energy consumption, greenhouse gas emissions and water demand.

Informed by an understanding of how current BASIX commitments perform under future climate scenarios, actions have been identified to enhance the climate resilience of residential housing of not only the Eastern Beaches region, but the whole of NSW. These actions will complement existing regulatory controls with Council-led initiatives to improve indoor thermal comfort, reduce energy consumption, greenhouse emissions and potable water use.

2.3 PROJECT STEERING COMMITTEE

A Steering Committee for the *Future Proofing Residential Development to Climate Change* project has been convened, which consists of a coalition of Councils, the Greater Sydney Commission (GSC) as well as two key directorates within the NSW Government's Department of Planning, Industry and Environment (DPIE). The project is funded by a NSW Government Increasing Resilience to Climate Change Grant; a partnership program between Local Government NSW (LGNSW) and the NSW Department of Planning, Industry and Environment (DPIE), which provides funding to address identified climate change risks and vulnerabilities facing NSW councils.

2.4 THE BUILDING SUSTAINABILITY INDEX (BASIX)

The objectives of this research project are to be pursued within the context of the BASIX regulatory provisions for residential development. BASIX was introduced in 2004 as NSW legislation in the form of the BASIX SEPP. The requirements for residential developments are enabled in the BASIX SEPP and in clauses under the EP&A Regulation 2000 that affect developments subject to BASIX assessment. BASIX verification is implemented through the online certification tool via https://www.planningportal.nsw.gov.au/basix.

The BASIX requirements are an integral part of the residential development application process in NSW. A BASIX certificate must accompany the Development Approval / Complying Development Certificate application and, where approved, construction must be in accordance with the BASIX commitments. All BASIX commitments are to be marked on construction plans and these commitments are subject to inspection by a certifying authority. A final Occupation Certificate can only be issued when the certifying authority is satisfied that the project has been built in accordance with the BASIX certificate.

BASIX is comprised of three modules to assess a dwelling's performance against a benchmark year and sets targets for thermal comfort, water use and energy use. The modules rely on localised climate information to determine a building's performance against each of these targets.

The thermal comfort component of BASIX requires all new residential dwellings to meet minimum requirements for annual heating and cooling loads. This is demonstrated with NatHERS-accredited modelling software. NatHERS considers a dwelling's design, construction materials and location to give a rating on its performance against benchmarks for air conditioning energy required to achieve acceptable thermal comfort. The system references historical weather data from the Bureau of Meteorology for 69 NatHERS climate zones defined across Australia, including hourly records of air temperature, wet bulb temperature, pressure, wind speed and direction, cloud cover and solar irradiance[1][2]. With this data, the internal temperature conditions and associated heating and cooling loads (in MJ/m^2) of a dwelling are estimated.

2.5 LITERATURE REVIEW

A brief review of literature relevant to this research has been undertaken to capture findings and issues raised by local Australian studies and to identify examples where such investigations have been undertaken internationally.

2.5.1 LOCAL CONTEXT

Various levels of government have begun addressing climate change preparedness with studies into current building design practices and regulations. In an initiative led by the Cooperative Research Centre for Low Carbon Living, the NSW Government and UNSW evaluated the performance of the BASIX tool. The study compared the actual and estimated energy consumption of BASIX-compliant dwellings, and then investigated the cause of the discrepancies between them. Overall findings showed that measured greenhouse gas (GHG) emissions were close to estimates, and generally slightly lower. Despite this, differences were found in the breakdowns for energy use across heating and cooling, lighting and appliance loads. Recommendations presented by the study focused on updating BASIX and NatHERS processes or construction policy, including the following recommendation:

- *Improve space cooling and thermal load estimations by considering the increasing frequency of extreme heat events, overall rise in temperatures, and occupant behaviour such as set points for systems.*

The same authors published a study similar to this project, although with a narrower focus. The study compared the current climate to that of 2030 for the Western Sydney locality of Richmond. As for this project, the study used RCP8.5 projection data to represent the 2030 climate.

As part of the Future Proofing Residential Development to Climate Change project, a small sample of Councils were surveyed to investigate the factors affecting sustainability in new residential developments. The survey identified barriers to delivering efficient, affordable and climate-resilient housing. It also recognised opportunities to overcome the barriers, provided ongoing commitments are made across all levels of government and industry.

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[1] https://www.nathers.gov.au/owners-and-builders/how-nathers-star-ratings-are-calculated

[2] NIWA (2017), Creation of NatHERS 2016 Reference Meteorological Years – 2016 Climate File NIWA Report https://www.nathers.gov.au/publications/creation-nathers-2016-reference-meteorological-years

Barriers identified included regulatory and compliance challenges with BASIX, with solutions centred around the themes of education, good quality datasets and provision of adequate resourcing.

- Respondents supported strengthening BASIX water and energy targets for new developments, with most viewing it to be outdated and not stringent enough.
- Concerns were raised that highlighted the need for use of more representative climate data. NatHERS approved software currently uses historical climate data from the period 1970–2004. The 10 globally hottest years on record have all occurred after 2004 (NOAA National Centers for Environmental Information, 2020) and are not accounted for at all in the current tools.
- Councils were also concerned with the lack of industry support or compliance to ensure that buildings are being built and certified to BASIX and NatHERS specifications.

Opportunities for improvements to efficient building design were identified across the respondents.

- That the BASIX scheme (calculations, data and targets) and NatHERS datasets are reviewed and updated regularly in line with best practice and changing climate conditions and;
- expansion of BASIX to promote best practice in the areas of waste, materials and transport was raised;
- extra support for local government was sought to incentivise programs for the retrofitting of existing dwellings;
- other initiatives relating to climate change adaptation are funded, including heat mitigation for dwellings, power generation and storage; flood and drought mitigation; and the development of resilience action plans.

An in-depth report on the impacts of climate change on building design and energy (DeltaQ, 2020) was undertaken on behalf of the COAG Energy Council and the Department of Industry, Science, Environment and Resources (DISER). Following a review of the current framework, international approaches, and modelling results of different climate scenarios, a set of recommendations were made to address climate change adaptation, summarised as follows:

- Updates to Section J of the National Construction Code to recognise the full life span of buildings as well as to revise the stringency of provisions, reflecting not only current climate conditions but also future climate projections.
- Introduce the requirement for the use of future climate data for energy and thermal comfort building modelling. These climate files should be managed by government and updated at a minimum of once per decade to account for the latest climatic changes and most up-to-date projections. Climate files should also be developed for urban areas experiencing impacts of urban heat island effect.
- Analysis of the impacts of changing carbon intensities from energy sources on the industry and greenhouse gas emissions.
- To improve climate resilience for new developments, a new requirement is recommended in the NCC that construction projects undertake a risk assessment for extreme weather events and implement risk mitigation strategies.

2.5.2 INTERNATIONAL STUDIES

An initiative by the Government of Canada (National Research Council Canada, n.d.) received CAD42.5M on studies to integrate climate resiliency across all areas of building and infrastructure design, guides and codes.

- Despite having a largely different environment to Australia, many of the challenges associated with climate change are relevant to both countries.
- Historical climatic design data within the National Building Code was deemed to be outdated.
- New climate data will also address future projected conditions with increasing global temperatures.

Areas of focus for buildings included:

- The development of safety guidelines to address the effects of extreme heat events, and

- building material and system durability and performance during such events.
- Adaption measures for the retrofitting of existing buildings to help manage performance and comfort are under investigation as part of the study.
- The impacts of disaster events such as floods and fires on building are also being addressed.
- National requirements for the design of flood resistant building are being developed for potential implementation on future editions of the building code.
- Similarly, a guide will be prepared to reduce the impacts of bushfires on buildings.

2.6 RESEARCH OBJECTIVES

2.6.1 PROPOSED RESEARCH QUESTIONS

This project aims to answer the following research questions:

1. How will changes in climate affect the future water use from BASIX compliant dwellings in 2030 and 2070?
2. How will changes in climate affect the future energy consumption and greenhouse emissions from BASIX compliant dwellings in 2030 and 2070?
3. How will changes in climate affect the thermal comfort of BASIX compliant dwellings in 2030 and 2070?

Potential considerations include:

- a How will these dwellings perform during the predicted average increases in temperature?
- b How will these dwellings perform during extreme weather events e.g. during a heatwave or extreme heat day?
- c How will these dwellings perform during a blackout? i.e. under a scenario with no access to mechanical space cooling

BASIX compliant dwellings refer to dwellings that satisfy the current BASIX mandatory requirements (effective from 1 July 2017) of potable water savings, thermal comfort and emission reductions at their design stage.

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The NatHERS Administrator. (2019). *NatHERS Technical Note (Version June 2019).* Department of Industry, Science, Energy and Resources, Commonwealth of Australia.

4 DETAILED METHODOLOGY

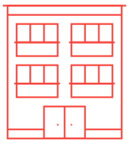
This research project examined five residential building designs typical to the Waverley, Woollahra and Randwick local government areas. The dwellings were modelled to understand predicted heating and cooling loads (thermal comfort) using NatHERS accredited software and the energy and water consumption were modelled using BASIX. The dwellings were assessed in accordance with the Baseline Year (2020) climate data, and under two future climate scenarios, a near-future scenario of 2030 and a far-future scenario of 2070, to establish the change in thermal comfort, energy and water consumption of these dwellings under future scenarios.

A sensitivity test of the results was conducted by comparing the heating and cooling loads from NatHERS to those generated using separate dynamic thermal modelling using IES VE thermal analysis software, to achieve greater granularity in the modelling results. This allowed a view of the distribution of temperatures throughout the year, the peaks and troughs in heating and cooling loads, the extent of time that extremes of temperatures are experienced and the likely conditions inside the dwellings in the occurrence of a blackout.

4.1 DWELLINGS

The research project tested a range of dwelling types to allow the impacts of a changing climate to be more fully appreciated.

Table 4.1 Test building categories and design sources

Dwelling Types Category	Number of Dwellings per Building	Design Sources
Detached 	**1**	Waverley Council
Attached 	**2**	Woollahra Council
Low-rise (up to 3 storeys) 	**9**	Randwick Council
Mid-rise (4 – 5 storeys) 	**10**	Woollahra Council
High-rise (6 storeys and above) 	**195**	WSP existing models located in Waverley Council

Dwellings were selected that met current BASIX targets (post-1st July 2017). Dwellings selected for the study were accompanied by deidentified plans and existing BASIX and NatHERS certificates for modelling purposes. The selected plans used in the analysis are provided in Appendix B below.

4.2 CLIMATE SCENARIOS, MODELLING TOOLS AND CLIMATE DATA

Three different study time periods were selected:

- Present Day (average 1990 – 2009), to serve as a Baseline Year
- Near future change 2030 (average 2020 – 2039)
- Far future change 2070 (average 2060 – 2079)

Table 4.2 Summary of evaluated performance factors, analysis software and climate data used

PERFORMANCE FACTOR	MODELLING SOFTWARE	FUTURE CLIMATE DATA SOURCES
Thermal comfort – cooling & heating loads (MJ/m^2) Baseline and future climate dry bulb air temperature	FirstRate5 v5.3.0a (NatHERS)	CSIRO RCP8.5 data set-NatHERS Climate Zone 56
	IES VE 2019	RCP8.5 Sydney Airport, EnergyPlus (epw) format for 2030 and 2070 (generated from Meteonorm 8.01 software)
Energy consumption and GHG emissions ($kgCO_2$-e / person / year)	BASIX online tool	NARCliM (NSW & ACT Regional Climate Model) data set, based on A2 scenario (IPCC high-emissions)
Water consumption (litres/person/year)		

- Dwellings were modelled to understand the thermal comfort performance of the dwelling, i.e. the predicted heating and cooling loads (measured in MJ/m^2) using NatHERS approved software.
- Energy consumption and resulting greenhouse gas emissions were measured in $kgCO_2$-e/person/year using the BASIX tool.
- Finally, water consumption of the dwellings was measured in litres of water/person/year using the BASIX tool.

4.2.1 FUTURE CLIMATE DATA

The variety of modelling software used in this study (NatHERS, IES and the BASIX tool) referenced the RCP 8.5 (Representative Concentration Pathway) climate projections for their future weather data. Sources for that data are provided in Table 4.2 above.

RCP 8.5 was selected for two reasons:

1. Current climate projections suggest that our trajectory to 2030 is following the RCP 8.5 path, and that even drastic intervention at this point is unlikely to deter that trajectory. Therefore, it is considered the more accurate prediction for the near future
2. The RCP 8.5 pathway is the worst-case scenario for the 2070 projection, providing the study with an extreme case for a 50-year forecast analysis.

BASIX CLIMATE DATA

NARCliM climate projections were provided by the Department of Planning, Infrastructure and Environment (DPIE) for the Bureau of Meteorology station located at Sydney Airport (Station identifier 66037). Station 66037 is the reference for the NatHERS Climate Zone 56. The NARCliM climate projections have been generated from four internationally recognised global climate models and are dynamically downscaled by three regional climate models[3].

The NARCliM data was used to update the BASIX tool for the future climate scenarios, with the publicly accessible BASIX environment serving as the Baseline Year reference. The methodology for the incorporation of the NARCliM data set into the BASIX tool is outlined in Appendix A below.

NatHERS climate files

Climate data projection files under a high emissions scenario (RCP 8.5) for Climate Zone 56 were provided by the CSIRO for 2030 and 2070, for the purposes of modelling building heating and cooling loads using NatHERS accredited software. This projection is one of the more extreme scenarios for future climate, with average temperature increases of up to 5° C predicted for the eastern region of Australia by the end of the century under RCP8.5[4].

IES Climate files

Dynamic thermal modelling was conducted using IES VE software as a sensitivity analysis of the results from the NatHERS modelling. To meet the data formatting requirements of this software, RCP8.5 future climate files in suitable format for IES were produced using Meteonorm 8.01 software for the Sydney Airport weather set, matched to the location of the data used in NatHERS and BASIX for this research.

4.2.2 BUILDING MODELLING SOFTWARE

BASIX

A research version of the BASIX tool was developed and provided by DPIE's BASIX Team, using projected data from the NARCliM climate data sets for 2030 and 2070.

NatHERS

Thermal comfort modelling was conducted using version 5.3.0a of FirstRate5 (FR5). FirstRate5 is a NatHERS accredited software package developed by Sustainability Victoria.

FR5 v5.3.0a utilises the recently updated Chenath simulation engine v3.21 developed by CSIRO.

4.3 ORIENTATIONS

The hypothetical dwellings were examined under different orientations, to understand the potential contribution that orientation choice could make towards the most suitable outcomes under future weather conditions.

A selection of dwellings from each building type were tested for the effects of changed orientation of the building. Eight increments of 45° were applied as orientation steps, starting from the as-certified design orientation.

Thirty-five (35) models in total were tested - all dwellings from the Detached, Attached, Low-rise and Mid-rise building types were sampled, along with a representative floor of dwellings from the High-rise. This allowed a representative sample of dwellings to be analysed.

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[3] https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/About-NARCliM

[4] Chen,S., Ren,Z., Tang,Z., Clarke,J., Round,V., and Chen,D. (2020). Constructing Future Weather Files for Building Energy Performance Simulation in Australia 1st Asia Pacific Conference on Sustainable Development of Energy, Water and Environment Systems, April 6-9, 2020, Gold Coast.

Dwellings designs rarely can use the most optimal orientation due to constraints of siting, block divisions and other planning constraints, and so this analysis helps to identify and comment where the designs tested may have been performing less than optimally from a passive design perspective.

4.4 MODELLING THERMAL COMFORT OF DWELLINGS

4.4.1 RATING THE THERMAL COMFORT PERFORMANCE OF BASIX SAMPLE BUILDINGS USING NatHERS

Original ratings of the BASIX compliant dwellings selected for this study may have used earlier versions of accredited software and the technical notes. Hence, each of the selected BASIX-compliant building designs listed in Table 4.1 above were re-calculated using the NatHERS accredited software.

The future weather climate files provided by CSIRO for this project were formatted to match the 'standard' weather files used by AccuRate, another of the software packages accredited for NatHERS regulatory modelling. This format is also consistent with the weather files used by FirstRate5 software.

To test the impacts of the three different climate scenarios, the same models were used for Baseline Year, 2030 and 2070, with a change to the Climate Zone 56 weather file between runs, by replacing the default zone 56 file with the relevant CSIRO future climate scenario file.

- Heating and cooling loads in MJ/m^2 for the three climate scenarios (Baseline Year, 2030, 2070) were generated, along with a list of requirements in NatHERS to achieve those loads.
- In the case of Mid-rise and High-rise MUD buildings, an appropriate, representative subsample of total apartments was selected for modelling and re-rating under the future scenarios.
- Modelling was performed in accordance with the current version of NatHERS Technical Note (Version June 2019).

The NatHERS heating and cooling loads generated were recorded in the thermal comfort section of the BASIX modelling tool under the three proposed climate scenarios.

4.4.2 SENSITIVITY ANALYSIS

To determine the effectiveness of NatHERS and BASIX in predicting the impact on energy consumption and thermal comfort under the given climate scenarios, two representative dwellings were modelled in thermal analysis software which can provide annual energy demand and consumption estimates and thermal comfort results in accordance with ASHRAE 55-2010.

The software used was IES VE 2019, developed by Integrated Environmental Solutions Ltd. Whole designs for Detached and Attached dwellings were used, whereas a single floor plan was examined for multi-storey dwellings. Their performance was analysed against the Baseline Year for reference and then compared against the 2030 and 2070 scenarios. The assessment compared:

- Estimated annual demand for heating and cooling, and associated energy use from a split ducted air conditioning system.
- Adaptive thermal comfort assessment of sample dwellings across the year, measured by hours that the building occupant is outside comfort conditions across the year.
- Performance of the dwellings on average across the year, on an extreme day and with no access to mechanical cooling.

5 RESULTS

Results of NatHERS modelling, BASIX compliance assessment and sensitivity analysis from dynamic thermal modelling have been analysed and are presented here in response to the research objectives outlined in section 2.6 above.

5.1 BASIX COMMITMENTS FOR EACH BUILDING TYPE

The term 'BASIX commitments' is typically used to describe the set of building design and technology choices that the Development Applicant commits to during the DA process, in order to get their building to pass the BASIX Water, Energy and Thermal Comfort targets. The listing of commitments in Table 5.1 below represent the settings that were established as the compliant case for each building type and which then were used to test under the three climate scenarios. **These settings remained constant throughout the tests.**

Table 5.1 Commitments applied for each BASIX sample building tested

BASIX Commitments	**Detached**	**Attached**	**Low-rise**	**Mid-rise**	**High-rise**
Site area	441m^2	718m^2	679m^2	728m^2	2,800m^2
Roof area	120 m^2	299m^2	396m^2	179m^2	950m^2
Rainwater tank capacity & capture area	✓ 5,000L 85m^2 of roof	✓ 5,000L each 125m^2 of roof	-	-	✓ 2,000L central 950m^2 of roof
Solar PV	✓ 0.84 kW	✓ 0.23 kW each	✓ 3.6 kW central	-	✓ 46 kW central
Constructions & Insulation					
Ground floor	Slab on grade / suspended slab	Slab on grade / suspended slab	Suspended slab	Suspended slab	Suspended slab
Upper floors	Concrete suspended slab	Concrete suspended slab			
Exposed floors added insulation	R2.0	R1.0	R1.0	R2.0	-
External walls	Reverse brick veneer, w/ plasterboard lining. R1.5 added insulation	Retaining wall Brick veneer w/ plasterboard lining. R1.5 added insulation	Concrete with plasterboard lining, R1.5 added insulation reflective air gap	Concrete with plasterboard lining, R2.0 added insulation	Concrete with plasterboard lining, R2.0 added insulation
Party walls	n/a	Triple leaf brick, plasterboard lining	Core filled blockwork, plasterboard lining	Cast concrete, plasterboard lining	Shaft liner with insulated studs, plasterboard lining
Internal partition walls	Plasterboard lined single brick + lightweight stud partitions	Plasterboard lined single brick, R2.0 added insulation to unconditioned	Lightweight stud partitions	Lightweight stud partitions	Lightweight stud partitions
Ceilings/Roof	Steel hip and gable main roof, R3.5 added insulation	Flat framed steel roof, R3.3 added insulation	Concrete slab, ceiling lining, R2.8 added insulation	Concrete slab, ceiling lining, R2.0 added insulation	Concrete slab, ceiling lining, R4.0 added insulation
Downlights	No downlight penetrations allowed for				
Exhaust Fans	150mm opening for sealed fans to kitchens, bathrooms, laundries				
Floor coverings	Living / kitchen / family – Timber Bedrooms/ WIRs – Carpet Wet areas – Tile	Living / kitchen / rumpus – Timber Bedrooms / Study / WIRs – Carpet Wet areas – Tile	Living / entry – Timber Beds / Study – Carpet Wet, kitchen – Tile	Living / dining / entry – Timber Bedrooms – Carpet Wet, kitchen – Tile	Living / dining / entry – Timber Bedrooms – Carpet Wet, kitchen – Tile

BASIX Commitments		**Detached**	**Attached**		**Low-rise**		**Mid-rise**		**High-rise**	
Glazing										
Frame type		Timber SGU	Aluminium DGU		Aluminium SGU		Comp. SGU	Al. DGU	Aluminium	
Glass		Clear float	Low-E Clear		Clear float	Low-E	Clear float		Clear DGU	Low-E SGU
U-value		5.4	4.3	4.9	6.7	5.4	5.9	4.8	4.8	5.6
SHGC		0.63/0.56 *	0.53/0.47	0.33	0.7	0.58	0.65/0.57	0.59/0.51	0.59	0.41
** The two SHGC values for windows are due to the frame fraction on different windows. For the same frame material and glass, fixed windows & sliding doors generally have a higher SHGC than awnings & other windows with more frame making up their total area.*										
Water Efficiency										
WELS fitting ratings	Showerheads	3 star (>4.5 / <6 L/min flow)	3 star (>4.5 / <6 L/min flow)		4 star (>4.5 / <6 L/min flow)		3 star (>4.5 / <6 L/min flow)		4 star (>6 / <7.5 L/min flow)	
	Toilet flushing	4-star	4-star		4-star		4-star		4-star	
	Kitchen taps	4-star	4-star		4-star		5-star		5-star	
	Bathroom taps	4-star	4-star		4-star		5-star		5-star	
Clothes washer WELS rating		Not specified for any building types								
Dish washer WELS rating		-	-		3.5-star		3-star		3.5-star	
Rainwater / Alternative Water Uses		Irrigation, Pool top-up	Irrigation, Pool top-up		-		-		Irrigation Car wash (1 bay)	
Swimming Pool		30kL, outdoor, covered, shaded	16.8kL, outdoor, covered		-		-		-	
Hot water recirculation		On demand	No		No		No		No	
Landscaping		50m², low water use species	174m² units, garden & lawn		129m² common, 50m² units, garden & lawn		319m² units, indigenous / low-water species		450m² common, garden & lawn	
Fire sprinkler system		-	-		-		-		Test water capture	
Energy Efficiency										
Hot water system		Gas instantaneous 3-star	Gas instantaneous 5-star		Gas instantaneous 5-star		Gas instantaneous 6-star		Central air-sourced heat pump, min. R1.0 piping insulation	
Ventilation	Bathrooms	Fan, interlocked to light switch	Natural		Fan, manual switched		Fan, manual switched		Fan, manual switched	
	Kitchens	Fan, manual switched	Fan, manual switched							
	Laundries	Fan, interlocked to light switch	Natural							
Cooling		1Φ, EER < 2.5, zoned air con. + ceiling fans	1Φ, 3-star air conditioning		1Φ, EER 2.5-3.0, zoned air con.		1Φ, 3-star air conditioning		1Φ, EER 3.5-4.0, zoned air con.	
Heating		1Φ, EER < 2.5, zoned air con.	1Φ, 3-star air conditioning		1Φ, EER 2.5-3.0, zoned air con.		1Φ, 3-star air conditioning		1Φ, EER 3.5-4.0, zoned air con.	
Lighting		Daylight available kitchen/bathroom	Daylight available kitchen/bathroom		LED lights, daylight available kitchen/bathroom in 6 of 9 units		LED lights, daylight available kitchen/bathroom in 4 of 10 units		LED lights	
Pool heating		Solar (gas boost)	Solar only		-		-		-	

BASIX Commitments		**Detached**	**Attached**	**Low-rise**	**Mid-rise**	**High-rise**
Kitchen		Gas cooktop Gas oven	Gas cooktop Electric oven	Gas cooktop Electric oven	Gas cooktop Electric oven	Induction cooktop Electric oven
Refrigerator		Not spec'd, well-ventilated space	-	Not spec'd, well-ventilated space	Not spec'd, well-ventilated space	Not spec'd, well-ventilated space
Clothes washer		Unspecified for any building types				
Dish washer		-	-	3.5 star	3 star	3.5 star
Clothes dryer		-	-	-	1.5 star	2 star
Clothes drying line		✓ Outdoor	✓ Outdoor	✓ Indoor	-	✓ Indoor
Car Park	Ventilation	-	-	Supply & exhaust, CO monitor with VSD fan	Supply & exhaust, CO monitor with VSD fan	Supply & exhaust, CO monitor with VSD fan
	Lighting	-	-	Fluorescent, motion sensor zoned switching	Fluorescent, motion sensors	LED, daylight + motion sensors
Waste Store	Ventilation	-	-	Exhaust only	Exhaust only	Exhaust only
	Lighting	-	-	Fluorescent, motion sensors	Fluorescent, motion sensors	LED, motion sensors
Lobby	Ventilation	-	-	None	None	Supply only, time clock/BMS controlled
	Lighting	-	-	Fluorescent, motion sensor zoned switching	LED, motion sensors	LED, daylight + motion sensors
Corridors	Ventilation	-	-	None	None	Supply only, time clock/BMS controlled
	Lighting	-	-	Fluorescent, motion sensor zoned switching	LED, motion sensors	LED, daylight + motion sensors
Other common areas	Ventilation	-	-	-	None	Comms – air con. w/thermostat. Storage – cont. supply & exhaust
	Lighting	-	-	-	Fluorescent, motion sensors	Comms - LED, manual switched. Storage – LED, time clock + motion sensors
Lift		-	-	1 lift, VVVF motor 4 levels, fluoro lighting	1 lift, VVVF motor, 6 levels, LED lighting	3 lifts, VVVF motor, 28 levels, LED lighting

5.2 BASELINE YEAR AND RCP8.5 FUTURE CLIMATE SCENARIO WEATHER

There is a trend upwards in the number of warm to hot days annually, as well as increases in mean and minimum temperatures, from the Baseline Year through 2030 and out to the 2070 climate projection data.

Temperatures in the climate data

The projected Eastern Suburbs (Climate Zone 56) climate conditions under these scenarios is therefore hotter for longer in a year, compared to historical weather statistics. An increase is therefore expected in the number of days and periods of time in each day for which air-conditioning cooling energy may be required to maintain occupant thermal comfort.

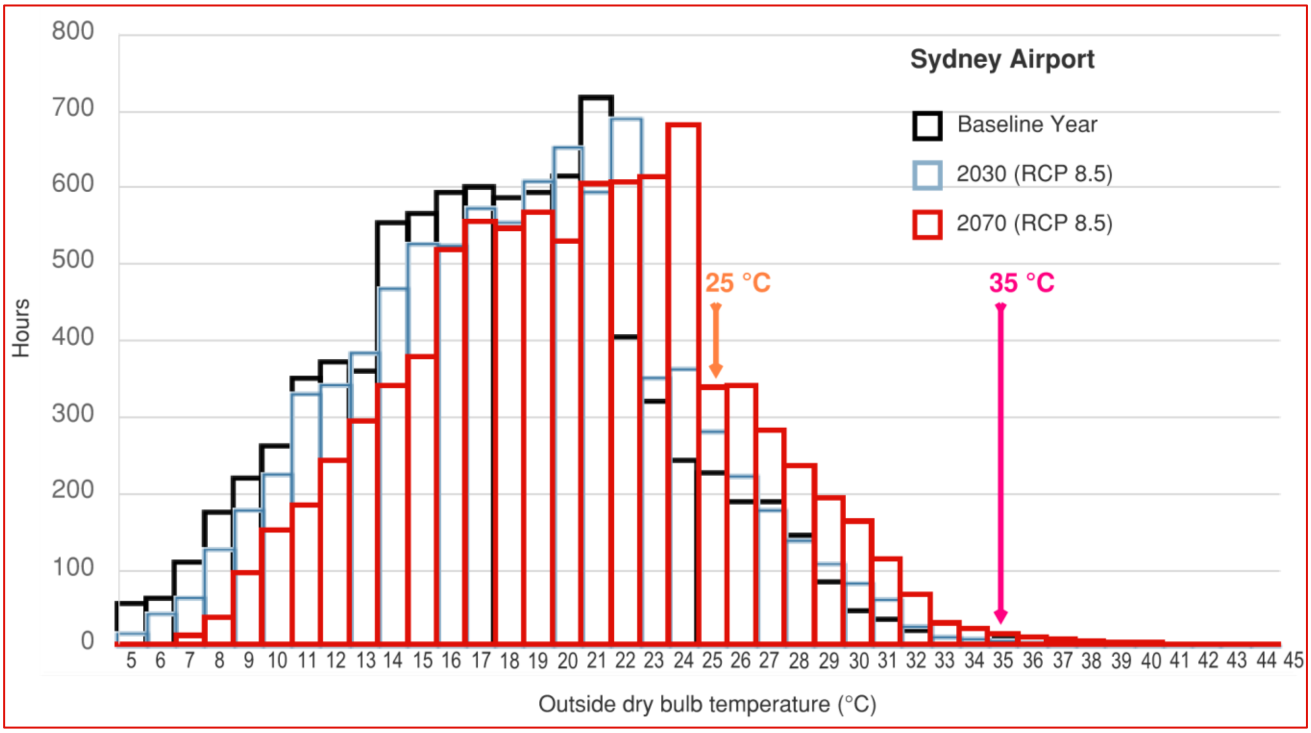


Figure 5.1 Frequency distribution of hours annually across the range of daily temperatures seen in the Sydney Airport weather data, overlaying Baseline Year, 2030 and 2070 histograms.

The histogram plot shown in Figure 5.1 demonstrates how the distribution of hours through the year at each temperature shifts towards the higher temperatures from the Baseline Year to 2030 to 2070.

The temperature that appears most frequently in all the hours through the Baseline Year is 21°C. In 2030 it is 22°C and by 2070 the most frequent temperature is 24°C.

There is also an increase in the frequency of occurrence for all temperatures above these marks in 2030 and 2070, demonstrating an increase in the proportion of hours that would be considered 'Warm' in the makeup of the year's temperature spread.

Table 5.2 summarises the annual number of warm and hot hours and days occurring in the Baseline Year, 2030 and 2070 weather data.

- Warm is any period that reaches or exceeds 25°C
- Hot is any period that reaches 35°C or over.

Table 5.2 Warm (>=25°C) and Hot (>=35°C) periods annually, for Baseline Year, 2030 and 2070 climate scenarios

	Baseline Year		2030		2070	
	Warm	Hot	Warm	Hot	Warm	Hot
Hours / year	1110	26	1323	28	2162	52
Days / year	125	5	150	6	200	9

The number of Hot hours and days doubles between the Baseline Year and 2070, but these *extreme days still only account for a small percentage of the whole year*.

It is the number of Warm days that appear to have the stronger influence on cooling needs for thermal comfort.

In the Baseline Year, Warm days account for roughly 34% of the year. However, by 2030 they account for 41%, and by 2070, Warm days occur for more than 54% of the year.

Amongst these warm days, the hot days will stress mechanical systems, placing greatly increased load on them to provide cooling comfort.

The following examples of the three climate scenarios from FirstRate5 for January and July in Figure 5.2 and Figure 5.3 show the shift in median outdoor temperatures upwards, and an increase in extreme days and temperatures.

Note the position of the charted temperatures relative to the orange 25°C line for the January series, and relative to the light blue 12°C line for the July series.

Maximum, median and minimum outdoor temperatures are all higher in the future climate scenarios compared to the baseline year, in both the warmest and coolest months of the year.

Figure 5.2 Comparison of January outdoor dry bulb temperatures, Baseline Year, 2030 and 2070

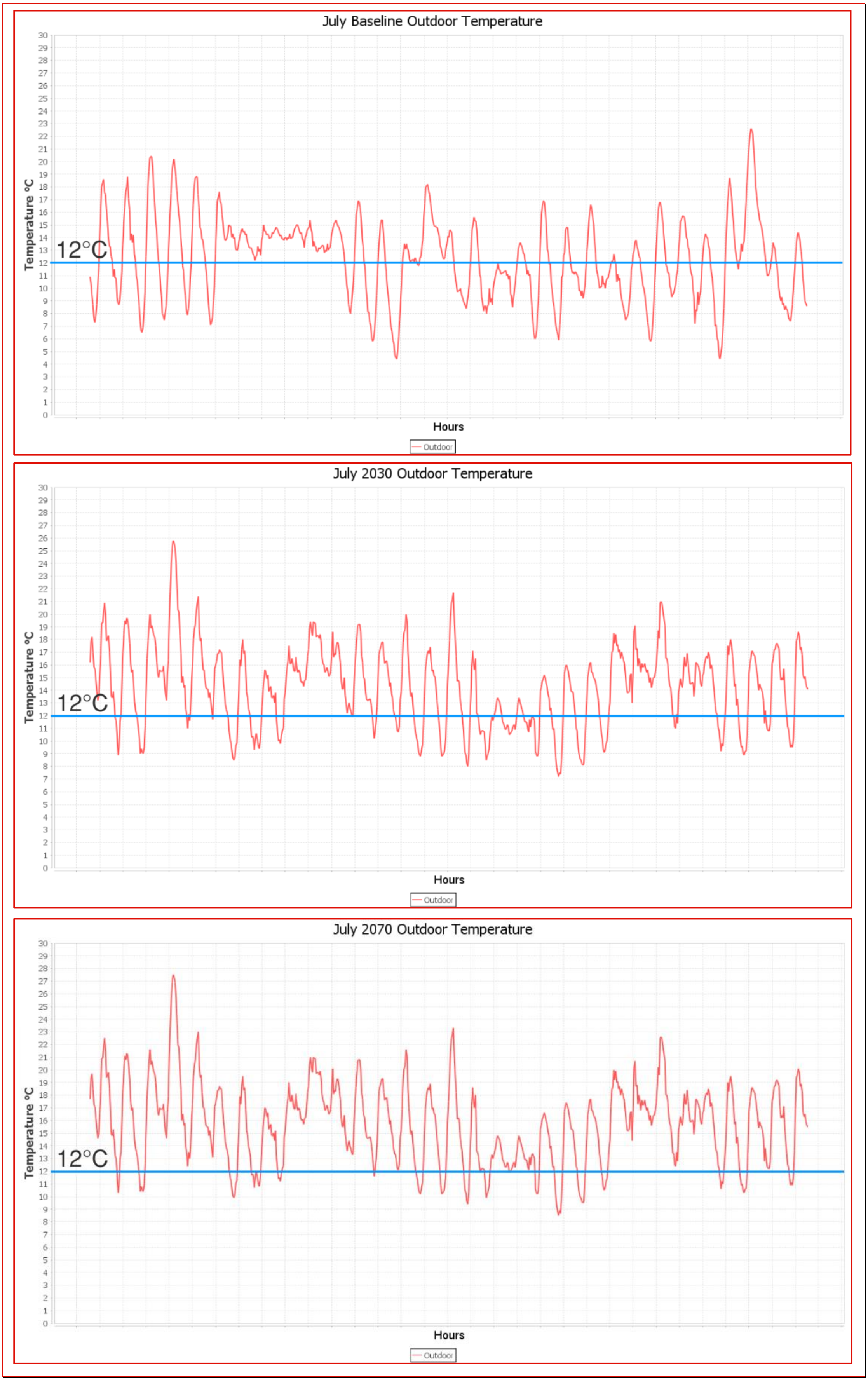


Figure 5.3 Comparison of July outdoor dry bulb temperatures, Baseline Year, 2030 and 2070

Climate data for rainfall and evaporation

As outlined in Appendix A below, NARCliM data is incorporated into the BASIX calculation algorithm to model the effects of projected climate changes on BASIX sample buildings. This brief summary describes the changes in monthly rainfall and potential evapotranspiration as predicted by the NARCliM tool for 2003 (the reference data year for Baseline), 2030 and 2070.

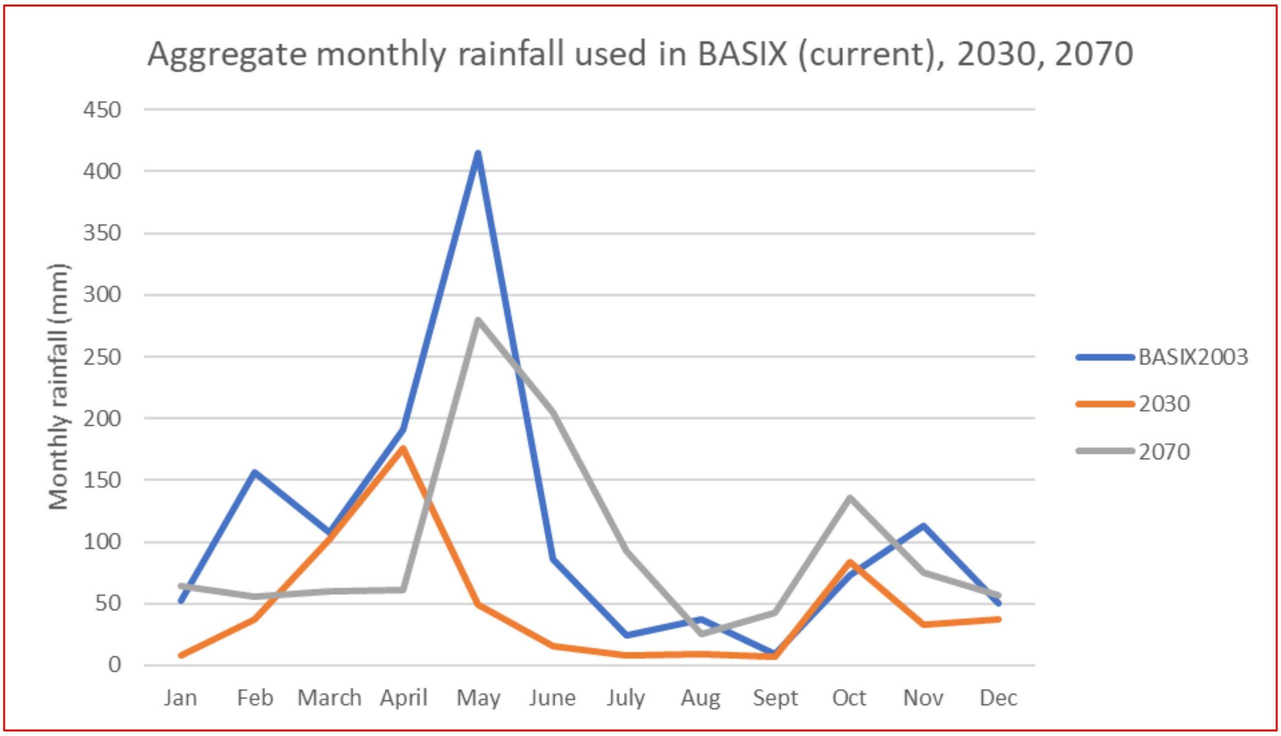


Figure 5.4 NARCliM rainfall data for the BASIX baseline year (2003) and projected 2030 and 2070 data sets

Under the NARCliM model, predicted rainfall is expected to drop from 1,316mm/year (2003 BASIX baseline year) to 567mm/year in 2030, and then increase again by 2070 to 1,153 mm/year.

The monthly distribution of rainfall for 2030 is significantly different to that used in the current BASIX tool, with a smaller April peak rather than the baseline prominent May peak. It also indicates a prolonged dry period between May and September not reflected in the baseline or 2070 data sets – this helps to explain the poorer BASIX water scoring results that are seen in the 2030 results, described in 5.5 Water Use Results below.

By comparison, 2070 is predicted to be a lot wetter than 2030 with higher total rainfall, a significantly higher peak in May and additional rainfall peaks at the start and end of the summer peiod. Again, this helps to explain the recovery from 2030 levels in BASIX Water scoring seen in the 2070 results of Table 5.6 below.

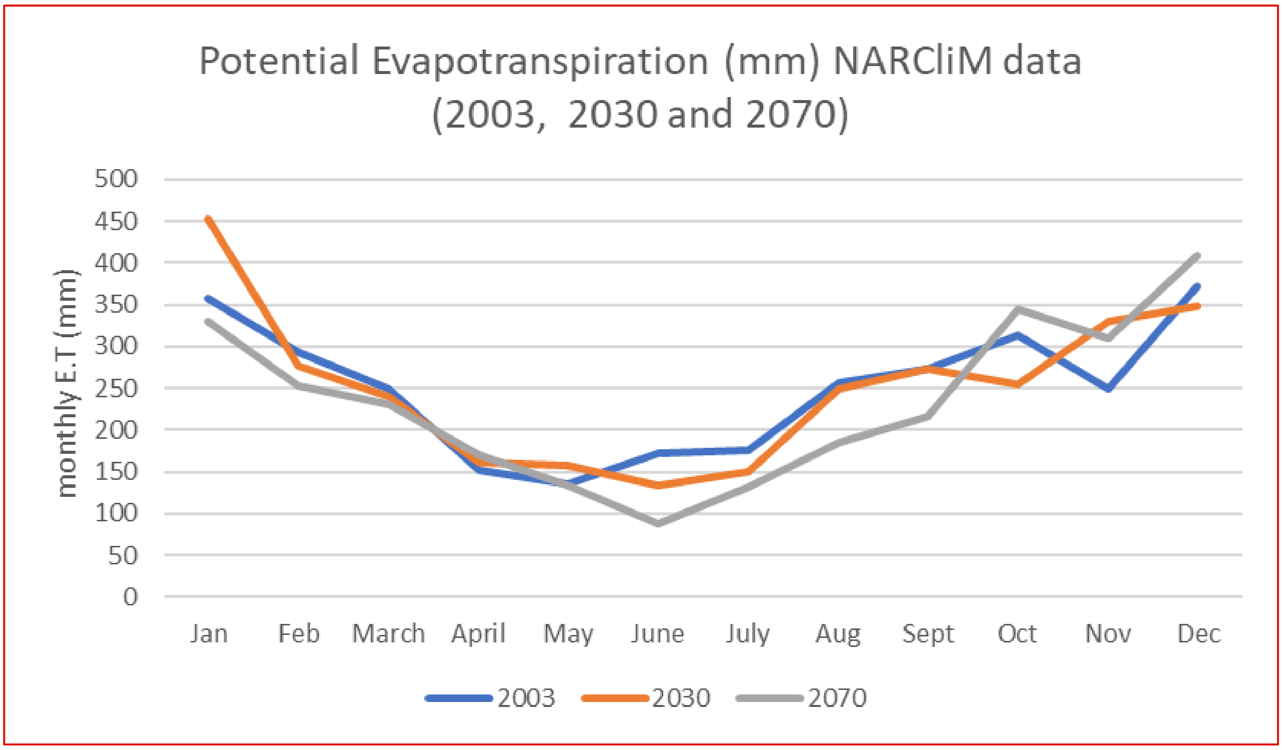


Figure 5.5 NARCliM evapotranspiration data for the BASIX baseline year (2003) and predicted potential 2030 and 2070 evapotranspiration rates

Overall, total annual potential evapotranspiration is broadly consistent between Baseline Year NARCLiM data (3,002mm), the 2030 projection (3,028mm) and the 2070 projection (2,802mm).

However, the profile of when the most and least evapotranspiration occurs shows small variations between the climate scenarios and further helps to explain the discrepancies in BASIX Water scoring as seen in Table 5.6 below.

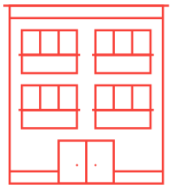
The NARCLiM future scenario data when compared to the Baseline year predicts increased rates of evapotranspiration through the Summer period (November to January) and lower rates between June and August, most pronounced in the 2070 data.

5.3 THERMAL COMFORT PERFORMANCE MODELLING RESULTS

5.3.1 NatHERS

The NatHERS thermal comfort results (modelled heating and cooling loads) of the selected dwellings and buildings types are presented in Table 5.3 below for the Baseline Year, 2030 and 2070 climate scenarios. Detailed individual dwelling results within each building are listed in Appendix D below.

Table 5.3 NatHERS thermal comfort modelling results for all building types and climate scenarios, Eastern Suburbs

		BASELINE YEAR				2030		2070	
		BASIX Targets		NatHERS Results		NatHERS Results		NatHERS Results	
Building Type		**Max. Heating (MJ/m²)**	**Max. Cooling (MJ/m²)**	**Heating (MJ/m²)**	**Cooling (MJ/m²)**	**Heating (MJ/m²)**	**Cooling (MJ/m²)**	**Heating (MJ/m²)**	**Cooling (MJ/m²)**
Detached				**30.9**	**20.8**	**8.8**	**37.3**	**2.1**	**91.6**
Attached				**22.2**	**23.8**	**7.1**	**40.9**	**1.9**	**102.5**
Low-rise		**40**	**26**	**31.7**	**25.8**	**12.9**	**40.0**	**4.6**	**91.2**
Mid-rise				**31.0**	**21.2**	**12.5**	**34.9**	**4.3**	**84.4**
High-rise				**26.3**	**15.5**	**13.9**	**27.4**	**5.6**	**65.0**

Results reflect what is seen in the RCP8.5 future climate scenarios weather data as described in section 5.1 above, responding to increased periods of warm temperatures annually and an increase in mean and minimum temperatures.

Dwellings currently compliant with the limits for heating and cooling will predominantly overheat in the 2030 & 2070 climate scenarios.

Key Findings:

- Under the 2030 and 2070 future climate scenarios, a distinct shift away from evenly-matched heating and cooling loads in the Baseline Year towards greatly increased cooling loads and substantially reduced heating loads.
- In 2030, cooling loads increased by 55%-79% above the Baseline Year, depending on building type. The heating loads dropped significantly, reducing to between 53% and 28% of the Baseline Year loads. Combined loads remained on par with the Baseline Year.
- In 2070, cooling loads significantly increased by 254%-340% above the Baseline Year. Heating loads dropped, down to 36%-8% of Baseline Year loads. Combined loads substantially increased, up to 67%-127% above the Baseline Year.
- Multi-unit dwelling (MUD) buildings (the low-, mid- and High-rise types) generally have lower loads per square metre than Attached or free-standing dwellings, due to the thermal benefits of many shared surfaces between dwellings and generally more compact layouts. This characteristic was reflected in the future climate scenario results as well as Baseline Year, being most pronounced in the High-rise example.
- The significant increase in cooling loads means that overall air-conditioning energy demand for maintaining comfort in warm periods will be much higher compared to the Baseline Year.

The above findings are demonstrated in Figure 5.6. The dominant feature of the future climate for thermal comfort is higher temperatures for more of the year in the Eastern Sydney locality, with some extra and hotter extreme heat days. The principles of climate responsive design would dictate that, in response to these results, residential building designs should be accounting for hot climate conditions to address primarily cooling comfort requirements most of the time.

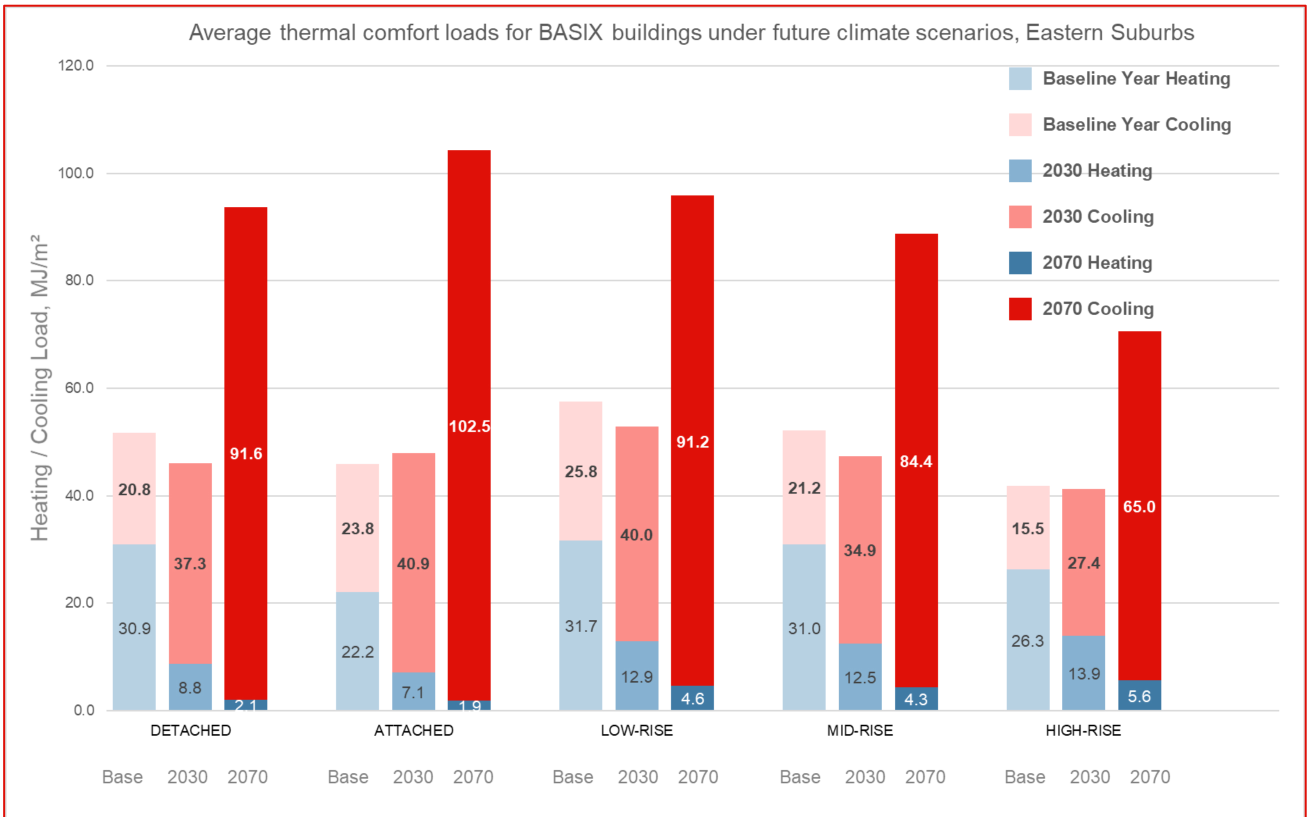


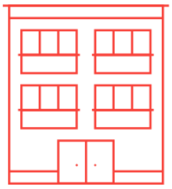
Figure 5.6 Comparison chart of average thermal comfort loads by building type, for Baseline Year, 2030 and 2070

5.3.2 ORIENTATION SENSITIVITY

A summary of the orientation sensitivity results is attached in Appendix F. Most designs tested demonstrated there were more optimal orientations than the orientation of the actual designs as certified, with only a handful in the Low-rise and Mid-rise buildings being the best orientation as designed and certified.

Table 5.4 provides a sample dwelling result from each building type, to show the orientation as designed compared to the orientation that would be needed to obtain the best cooling load result with no other interventions to the design. (North at 0° is vertically up the plans as drawn, with positive rotation being in a clockwise direction).

Table 5.4 Example orientation test results from each building type, Eastern Suburbs

BUILDING TYPE	NORTH ORIENTATION RELATIVE TO PLAN AS DESIGNED	OPTIMAL ORIENTATION (DESIGN ROTATION NEEDED)
DETACHED 	**351°**	**261° (+270°)**
ATTACHED 	**358°**	**88° (+90°)**
LOW-RISE 	**81°**	**81° (0°)**
MID-RISE 	**352°**	**82° (+90°)**
HIGH-RISE 	**352°**	**82° (+90°)**

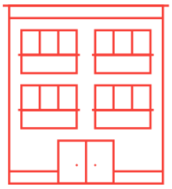
Selection of the most optimal orientations would be one option to employ in minimising the increases in demand for cooling energy under the future conditions.

Constraints of lot sizes in the eastern suburbs may limit the ability to optimally orient a building.

However, the orientation of primary glazed areas and placement of shading can be influenced by these findings, being primary passive design elements that influence heat gains from solar radiation on a building.

5.4 ENERGY USE AND GREENHOUSE GAS EMISSIONS RESULTS

Table 5.5 Summary BASIX Energy results for all building types and climate scenarios tested, Eastern Suburbs

TYPE	TARGETS	BASELINE YEAR	2030	2070
DETACHED 	Energy 50	**50**	**50**	**45**
ATTACHED 	Energy 50	**50**	**48**	**42**
LOW-RISE 	Energy 45	**45**	**45**	**40**
MID-RISE 	Energy 35	**37**	**36**	**32**
HIGH-RISE 	Energy 25	**30**	**30**	**27**

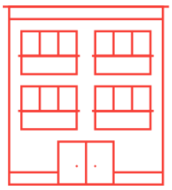
Red coloured scores in Table 5.5 indicate the building fails to achieve the BASIX Energy target. The Energy Scores in BASIX are only slightly impacted by a warming climate, if compared to the degree of change seen for Thermal Comfort and Water performance. This is explained as the increased energy cost of cooling homes being largely, though not completely, offset by the reduced energy cost to heat homes in Winter, with most other energy uses within the dwellings being not greatly affected by climate conditions.

In the 2030 scenario, all building types except the Attached building achieved a pass rate according to BASIX Energy requirements. However, in the 2070 scenario the increased energy demands (due to greatly increased cooling needs) caused four of the five building types to fail. The High-rise building passed due to the benefits from economies of scale and access to renewable energy provision in their original design.

5.5 WATER USE RESULTS

Table 5.6 lists the resulting BASIX water scores for each of the building types under each of the climate scenarios tested.

Table 5.6 Summary BASIX water use results for all building types and climate scenarios tested, Eastern Suburbs

TYPE	TARGETS	BASELINE YEAR	2030	2070
DETACHED 	Water 40	**40**	**-21**	**6**
ATTACHED 		**41**	**-9**	**16**
LOW-RISE 		**40**	**24**	**29**
MID-RISE 		**41**	**18**	**24**
HIGH-RISE 		**40**	**39**	**40**

These broadly reflect the increasingly warm climate and its impacts on rainfall and evapotranspiration rates (the combined effects of evaporation losses and uptake of moisture by vegetation from the soil), resulting in poorer, non-compliant future performance in all but the High-rise building type case.

Key Findings:

- The results show the water score decreasing significantly across all building types in the 2030 scenario in response to the change in rainfall patterns. In 2070 the scores are slightly improved, in response to the climate scenario representing an increase in intensity of rainfall events between 2030 and 2070.

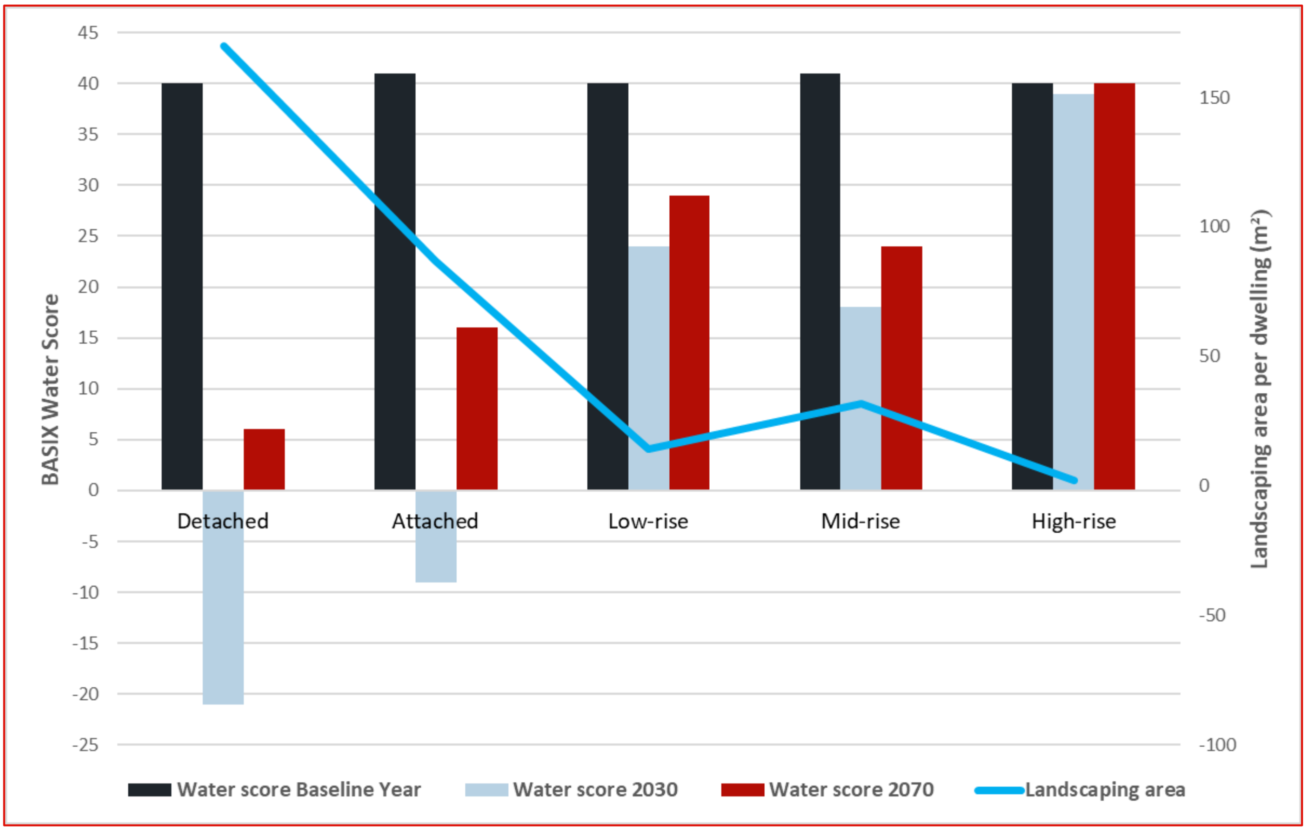


Figure 5.7 Relationship between landscaping area and BASIX water score across the five building types and Baseline Year, 2030 and 2070 climate scenarios.

Those dwellings that have the greatest extent of landscaped and vegetated area associated with them demonstrated the greatest impacts on Water scoring in the future climate scenarios. Conversely those with the least vegetated area were best able to maintain performance close to the Baseline Year score. Figure 5.7 visualises the comparative performance of Water scoring against vegetated area across building types and the three climate scenarios.

The inclusion of a rainwater tank that is connected for landscape irrigation purposes assists the Baseline Year case to achieve the Water target, however this has limited benefit to the future climate scenario score as it is already optimally utilised and does not offer surplus capacity for addressing the changed rates of evapotranspiration in the future.

Mitigation of poor water scoring

Although it was not part of the scope of this study, WSP investigated options for enabling the Detached dwelling to achieve compliance with the water score in the 2030 scenario. This test involved increasing the water tank size, removing the pool, reducing landscaping, maximising efficiency on all appliances and fittings, and installing a greywater treatment system for reuse in the washing machines and toilets.

It was found that even with all these treatments, it was not possible to achieve a compliant water score of 40.

This suggests further investigation is required in relation to the calculations undertaken by the BASIX calculator to determine the water score, or the benchmark for compliance may need to change if the climate file used in BASIX is updated to the current 2030 climate scenario. This conclusion is drawn from the fact that if the Detached dwelling was not able to meet compliance with the above-mentioned treatments, then it is highly likely that no Detached dwellings will be able to, and Attached or multi-unit buildings may face similar challenges.

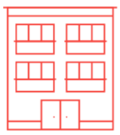
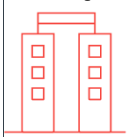
5.6 KEY RESULT FINDINGS

Key findings from the results that will be discussed include the following:

- Cooling loads for thermal comfort
- BASIX Energy scores
- BASIX Water scores
- Heat extremes - Warm days (>25°C) and Hot days (>35°C)

These elements of the results are summarised in Table 5.7 below.

Table 5.7 Baseline Year, 2030 and 2070 comparison of average cooling loads, BASIX Energy and Water scores and Extreme Heat conditions in each scenario

TYPE	BASELINE YEAR				2030				2070			
	Cooling Load (MJ/m²)	BASIX Energy	BASIX Water	Extreme Heat	Cooling Load (MJ/m²)	BASIX Energy	BASIX Water	Extreme Heat	Cooling Load (MJ/m²)	BASIX Energy	BASIX Water	Extreme Heat
DETACHED 	20.8	50	40	WARM 125 d / 1110 h HOT 5 d / 26 h	37.3	50	-21	WARM 150 d / 1323 h HOT 6 d / 28h	91.6	45	6	WARM 200 d / 2162 h HOT 9d / 52h
ATTACHED 	23.8	50	41		40.9	48	-9		102.5	42	16	
LOW-RISE 	25.8	45	40		40.0	45	24		91.2	40	29	
MID-RISE 	21.2	37	41		34.9	36	18		84.4	32	24	
HIGH-RISE 	15.5	30	40		27.3	30	39		64.2	27	40	

(Red text indicates where a building has not achieved the required BASIX target for the element and climate scenario shown.)

5.7 DISCUSSION OF KEY FINDINGS

In keeping with the research basis of this work and to provide evidence-based reasoning for further investigation, discussion of the findings in this section addresses the following aspects of the study:

- Responses to the research questions
- Reflection on the methodology
- Policy recommendations for residential preparedness and resilience measures for a changing climate.
- Suitability of the regulatory framework around BASIX for future proofing design

5.7.1 *HOW WILL CHANGES IN CLIMATE AFFECT THE THERMAL COMFORT OF BASIX COMPLIANT DWELLINGS IN 2030 AND 2070?*

Modelling results indicate that as the climate warms into 2030 and 2070, dwellings in the Eastern Suburbs will have minimal requirements for heating. However in Summer, cooling demand is predicted to dramatically increase. **All dwellings tested failed the current BASIX Thermal Comfort requirements for cooling in 2030 and 2070**.

The modelled cooling loads of the Detached dwelling type exceeded the BASIX cooling caps by approximately 150% in 2030 and 350% in 2070. The most adversely impacted dwellings were the Attached, Detached and Low-rise buildings.

Our residential dwellings need to be designed *now* for the 2030 climate scenario, because buildings built to the current standards will have a higher cooling load than expected when they are less than 10 years old.

How will these dwellings perform during the predicted average increases in temperature?

This can increase demand for air conditioning cooling energy, with potential for secondary impacts on infrastructure requirements and electricity supply.

The broader spread of warm days through the year shown in the temperature plots (refer to Figure 5.2, Figure 5.3 and Figure 5.1 above) helps to explain the increased need for cooling, due to an increase in the overall number of days and hours that cooling energy will be required, rather than just the increased number of 'Hot' days greater than 35°C. Mechanical cooling systems can be expected to operate for longer during the year, for the most part at temperatures within the normal operating parameters of the systems.

How will these dwellings perform during extreme weather events e.g. during a heatwave or extreme heat day?

It can be expected that there would be an increase in demand for air conditioning during heatwaves and extreme heat days, the question remains if there will be capacity in individual dwelling mechanical systems to meet the comfort conditions.

NatHERS outputs, being an annualised result reported as energy per unit area per year, do not provide the granularity of results to allow direct interrogation of the frequency or intensity of cooling demand.

As noted above, the total number of peak days of extreme heat in the typical projection of annual weather, despite doubling, remains a small part of the whole year. Residents who are in a position where they either cannot install or cannot afford to operate air conditioning systems on extreme heat days will potentially have to deal with severe thermal *dis*-comfort within their dwellings.

As would be the case currently on such days, there are health hazards associated with dehydration and heat stroke that typically are of greatest risk to the more vulnerable of residents including the more elderly, infants and those with existing health conditions.

Mitigation measures may be required that could include ensuring adequate hydration, cool bathing or showering, avoiding additional heat gains through employing blinds and shading, increasing air movement with fans and most probably vacating the premises during the peak heat part of the day and seeking shelter in public air conditioned areas such as shopping centres and other public facilities.

How will these dwellings perform during a blackout? i.e. under a scenario with no access to mechanical space cooling

The outdoor temperatures indicated in the 2030 climate scenario weather data suggest that residents will be exposed to more frequent peak days and therefore could experience more frequent discomfort during blackouts on Hot days.

Under the 2070 climate scenario, the peak temperature Hot days increase in both frequency and magnitude of the peak. For example, Figure 5.2 above shows that the January peaks increase by approximately 1.5°C to 2.0°C between the 2030 and 2070 climate scenarios. We can assume that discomfort may rise to unacceptable levels if blackouts occur on peak days, as they would currently be intolerable during extreme heat events, and this demonstrates the same events in 2070 would be potentially more frequent and result in even hotter internal conditions.

To aid this discussion, the Attached building thermal comfort results are visualised here in Figure 5.8, Figure 5.9 and Figure 5.10 as an example of predicted internal conditions over the January period in each climate scenario. The key temperature peaks where internal conditions would become increasingly less tolerable are circled on the charts. Similar charts are provided for the warm period months October to March in Appendix E below.

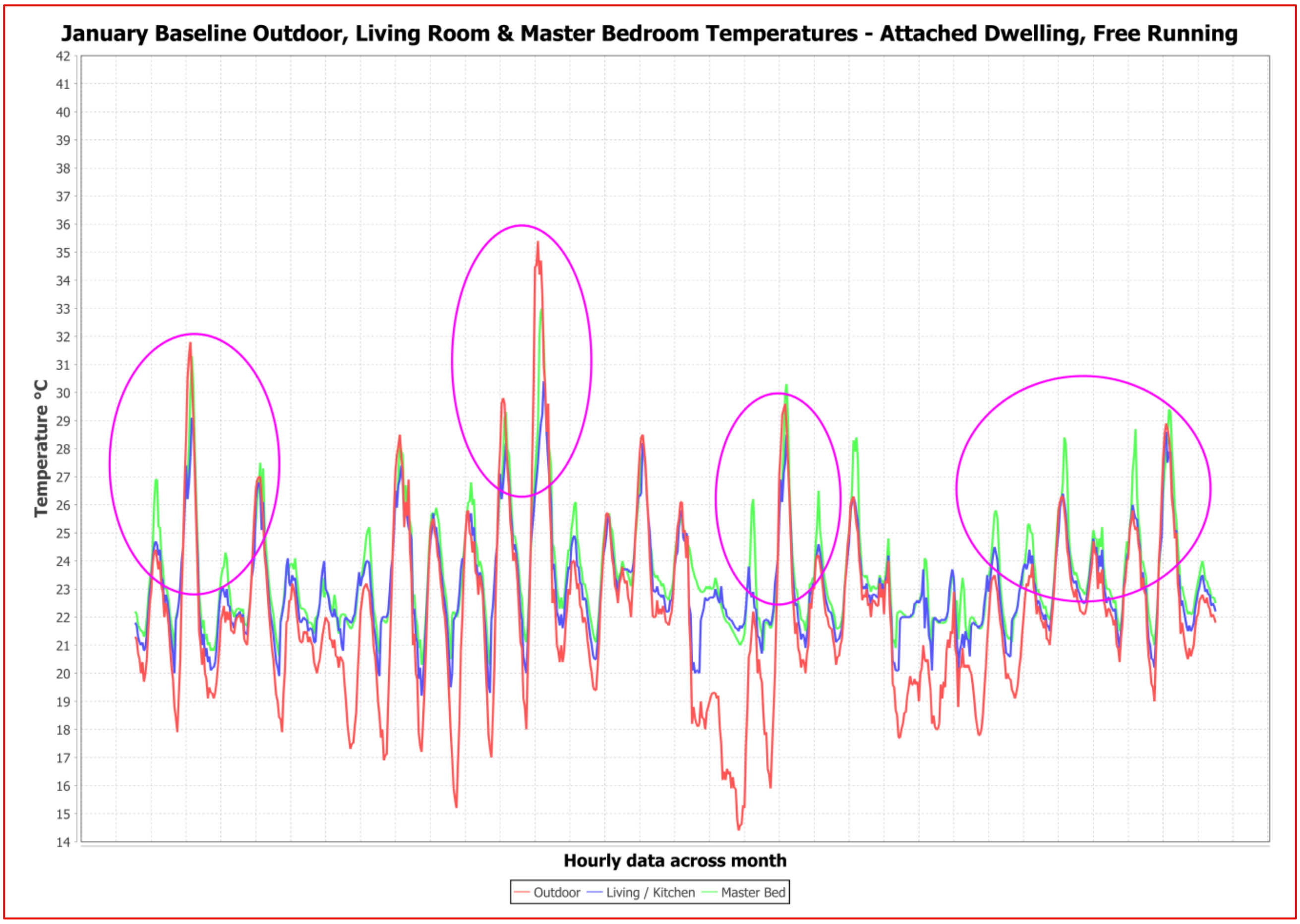


Figure 5.8 Baseline Year January temperature plot, Attached dwelling type, **Outdoor air**, **Living Room** & **Master Bedroom** temperatures.

The Living Room of the Attached Building type mostly tracks with and at times overshoots the outdoor air temperature peaks when the dwelling is modelled without air conditioning operating (‘free run’ mode in FR5).

The Master Bedroom consistently overshoots the outdoor temperature peaks; while not as likely to be occupied during peaks because they occur in daytime, this shows that bedrooms would be unacceptably warm and offer no respite to occupants as an alternative to the main living areas under such adverse conditions.

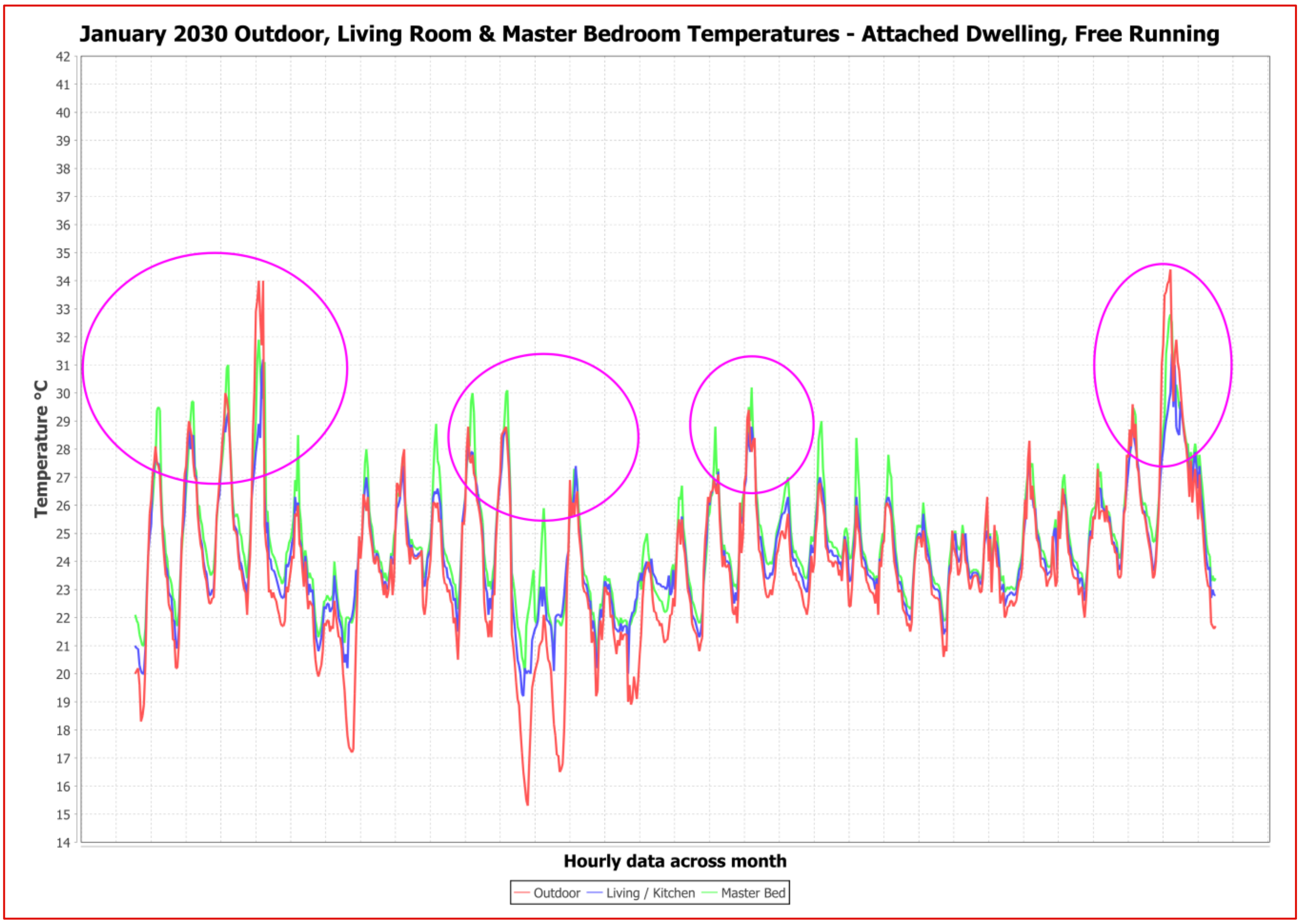


Figure 5.9 2030 temperature plot, Attached dwelling type, **Outdoor air**, **Living Room** & **Master Bedroom** temperatures.

While the Living Room and Master Bedroom temperature responses are similar in all scenarios, including Baseline Year as in Figure 5.8 above, the internal peak temperatures become much higher in the future climate scenarios, with potentially intolerable thermal comfort conditions during a loss of power particularly by 2070 (Figure 5.10 below).

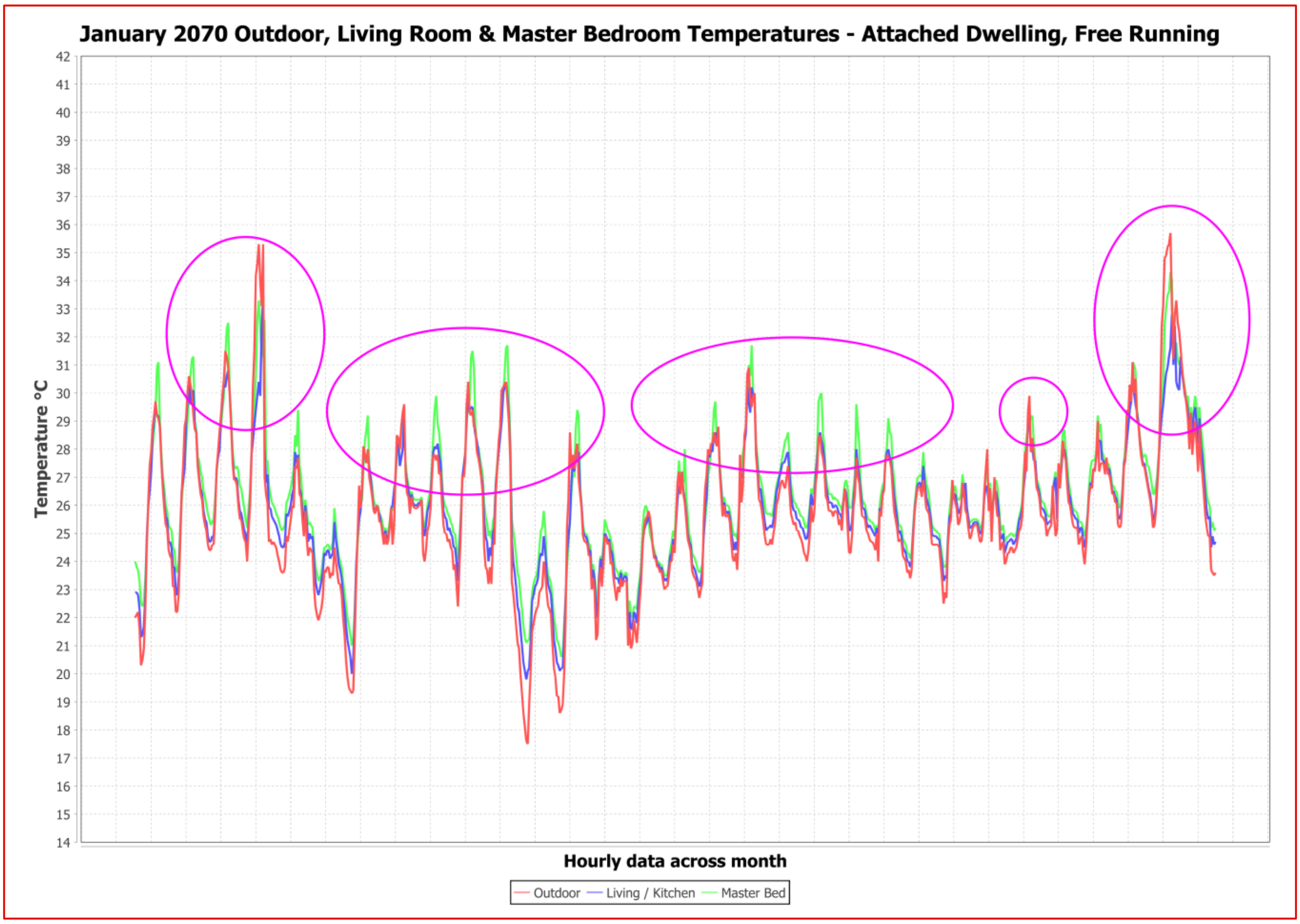


Figure 5.10 2070 temperature plot, Attached dwelling type, **Outdoor air**, **Living Room** & **Master Bedroom** temperatures.

The dominant feature of the future climate for thermal comfort is higher temperatures for more of the year in the Eastern Sydney locality, with some extra and hotter extreme heat days. The principles of climate responsive design would dictate that, in response to these results, residential building designs should be accounting for hot climate conditions to address primarily cooling comfort requirements most of the time.

The buildings most affected by heat were the Attached, Detached and Low-rise buildings. The least impacted dwelling type was High-rise building, benefitting from design factors such as a higher proportion of shared walls, floors and ceilings between dwellings compared to other building types as well as extra height contributing to better natural ventilation opportunity for upper level dwellings. Despite this, the High-rise building exceeded the current acceptable cooling load by a factor of about 250%.

It is possible that dwellings approved for construction now will be unsuitable for occupation by 2070, without extremely high levels of mechanical cooling to maintain comfortable, safe and liveable conditions.

The thermal comfort modelling results from this study indicate that NSW will need to plan for greater design requirements from residential buildings to keep cool, to maintain acceptable passive thermal comfort conditions and help to mitigate future increased demands for mechanical cooling.

It is recommended that:

— The climate files used for NatHERS regulatory software are updated to a data set more representative of the current and anticipated future climate scenario, to ensure dwellings are designed to withstand future conditions;

— Design modifications are investigated for different building types to guide the Thermal Comfort policy setting in BASIX under future climate scenarios; and

- The heating and cooling load balance in BASIX Thermal Comfort requirements is reviewed, with particular reference to the cooling cap.

5.7.2 IMPACTS OF CLIMATE ON FUTURE ENERGY CONSUMPTION FROM BASIX COMPLIANT DWELLINGS

Modelling results from BASIX show overall energy consumption was only slightly impacted by a warming climate. The investigation showed there to be minimal impact on energy scores in the 2030 climate scenario. This is because the thermal comfort performance does not typically have a big impact on the Energy score, however this effect can be more pronounced where the Thermal Comfort targets are not achieved, as seen for most dwellings in the 2070 scenario.

The relatively small impact on Energy scores (when compared to the effects of future climate on the Thermal Comfort and Water scoring parts of BASIX) can be explained in part by the increased energy needed for cooling homes being offset by reduced energy needed to heat homes in cooler months. The makeup of energy scoring in BASIX also accounts for multiple energy uses in a home apart from air-conditioning that don't change in response to increased temperatures, thereby limiting any impact on Energy scoring.

In the 2030 scenario, all building types except the Attached dwelling type achieved the BASIX minimum Energy score.

However in the 2070 scenario, increases in energy demands (due to greatly increased cooling energy needs) caused four of the five building types to fail BASIX. Only the High-rise building passed due to economies of scale in the larger number of units in the building compared to other types.

Impacts from common area energy uses were spread over a greater number of units, and the greater ratio of shared walls, ceilings and floors to external surfaces for each dwelling helped to manage the thermal comfort loads and demands for air conditioning energy. Inclusion of renewable energy in the design and implementation of the Baseline case further assisted the High-rise building to pass BASIX Energy requirements when tested under the 2070 climate scenario. The building scored more than the minimum target in the Baseline Year case, and this buffer was sufficient to achieving the minimum Energy target in 2070.

Design Comment

Fundamental design changes are required for future housing, as they will need to be designed for hotter climates rather than incorporating tweaks to the existing approaches to design.

This applies both to the passive design elements of the construction itself (shading, glazing performance, ratios of glazing to opaque elements, selection of construction materials) and to some of the energy consuming services in the dwelling, including improved efficiency of air conditioning systems.

The Energy modelling results from this study indicate that NSW will need to plan for greater mechanical cooling demands in the future, both from a peak demand management perspective and to reduce greenhouse gas emissions. In addition, NSW will need to consider equitable access to cooling and the potential grid implications of providing this, to ensure continued affordability and availability.

In conjunction with the recommendations for Thermal Comfort above, it is recommended that:

- The BASIX heating and cooling calculations for Energy scoring are reviewed against the impacts of current and future climate on thermal comfort and the need for improved performance from air conditioning systems.
- A review of BASIX Energy scoring targets and provisions for multi-unit developments be undertaken. These attract lower target scores for Energy than attached and detached dwellings, which accounts for the inherent efficiency advantages for dwellings in higher density developments. However for improved reductions in both overall emissions and peak energy requirements, common areas and shared facilities can be encouraged to further contribute to efficiency measures as well the provisions within individual dwellings.

5.7.3 IMPACTS OF CLIMATE ON FUTURE WATER USE FROM BASIX COMPLIANT DWELLINGS

All building types failed to achieve the BASIX Water minimum target of 40 in the 2030 scenario, with significant reduction in score compared to the current scenario.

The worst performing dwelling type was the Detached house, which had a BASIX Water score of -21 in the 2030 scenario. This means that the same house will be using 61% more potable water compared to the house modelled for the Baseline Year. This is due to three main factors including; less rainfall being captured in the rainwater tank; more water being needed to keep the 170m² of landscaping alive and more water required to top up swimming pools due to evaporative losses.

By comparison, the least impacted building type was the High-rise multi-unit building, which achieved a BASIX Water score of 39 in the 2030 scenario, just 1 point below a pass. This building has 195 apartments, and only 450m² of landscaping, i.e. 2.3m²/dwelling. Therefore, the relative impact of rainfall reliability and increased transpiration on landscaping does not have a large impact on the water consumption of the building. The sample building assessed did not have a swimming pool associated with it; a greater impact on water scoring would be expected if a pool were included, due to the increased demand for top up water coupled with the changes to rainfall and evaporation effects.

Pools will also impact the water score, however in this test only the Detached dwelling had a pool, therefore the true impact of this cannot be seen. Further investigation into how BASIX buildings perform with pools is recommended, particularly once climate data is updated in the BASIX tool. In the 2070 scenario, the impact on the water score is not as significant, it is expected that this is because that climate scenario has an increased proportion of rain predicted.

NSW will need to plan for greater water demand from the residential sector due to the projected warmer climate. Given the uncertainties in rainfall under future climate scenarios, rainwater tanks may not be as reliable to reach the BASIX Water target in future. Alternative water supplies may play a role in meeting the Water targets, with consideration of treated storm water and recycled water reticulation suggested as two possible solutions. Landscaping calculations for water consumption in BASIX may also need to be revised.

It is recommended that:

- The BASIX tool is updated with climate data that more accurately represents the near-term and longer-term future drier climatic conditions that these buildings and their occupants will need to withstand.
- The BASIX calculations are reviewed in relation to outdoor water consumption (particularly the landscaping irrigation assumptions), given the predicted shifts in rainfall and evaporation for NSW.
- Once the climate data is updated and the calculations are reviewed, further testing of different building examples is completed to ensure that all building types can meet the BASIX Water targets.

5.7.4 REFLECTION ON THE METHODOLOGY

General Notes

1. Appliance efficiency was held constant across the future climate scenarios (2030 and 2070). It is anticipated that technologies will improve in efficiencies over time, however this was beyond the scope of this project.
2. This research did not account for greening of the grid, i.e. the forecasts used for BASIX Energy do not include future emissions projections for 2030 and 2070. Whilst it is recognised that the grid will continue to decarbonise, it was beyond the scope of this research. With anticipated improvements to the greenhouse gas emissions intensity of the grid, the emissions impacts addressed by BASIX Energy scoring in the future will be of less significance than peak demand issues and heat stress implications arising from substantial increases in cooling energy demand.

3 Behavioural changes in the use of water during periods of drought is not included in the modelling, and could mitigate the negative impacts on scoring to some extent. For example, under recent water restrictions anecdotal evidence and casual observation suggested that many homeowners allowed lawns to brown off rather than continuing to irrigate them.

NatHERS

The methodology applied in this investigation is not necessarily a statistically sound sample for each dwelling type. However, the number of dwellings studied provides a sufficient number to indicate that there is a concern with the potential performance of residential dwellings of all types in the future climate scenarios that have been tested.

5.7.5 POLICY RECOMMENDATIONS FOR RESIDENTIAL PREPAREDNESS AND RESILIENCE

- Designing for hotter climates
- Updating the climate files used for regulatory compliance.

Policy at the regulatory, state and local government levels should be reviewed and written in support of these overarching recommendations. This can potentially adopt the outcomes of suggested actions in section 5.8 below.

5.7.6 REGULATORY FRAMEWORKS FOR FUTURE PROOFING DESIGN

Future proofing residential design can be regulated at the national, state and local government level. These avenues are described below:

NATIONAL

NatHERS is the national tool used for regulating passive and performance design of residential construction to achieve acceptable thermal comfort. It is apparent from this study that an update to the climate files which are used in the NatHERS approved software would enable dwelling design to be measured against more appropriate performance for future conditions. This needs to be addressed at a national level by the NatHERS Administrator and NatHERS Steering Committee.

This research has implications not only for the Eastern Suburbs, but across NSW and the country. Further research is recommended to identify design modifications for different building types to guide the thermal comfort policy settings in BASIX under future climate scenarios.

STATE

The NatHERS star ratings or heating and cooling loads which must be achieved are determined at a state level. Therefore changing the BASIX compliance requirements can be addressed by State Government, which in the case of NSW would come under DPIE. Without changing the climate file in the software, it may be challenging to set appropriate cooling load limits for the different dwelling types and the many climate zones found across NSW.

LOCAL GOVERNMENT

Local Councils can be restricted in their ability to require performance beyond what is already included in legislated planning controls. Development Control Plans may include requirements which go beyond state and national legislation, however as for the State Government level, it is not possible for Local Councils to change the way NatHERS software is used – i.e. enforce the use of different climate files for BASIX.

Councils can strengthen their non-BASIX sustainability requirements for residential development through their DCPs and LEP; focusing on waste minimisation, sustainable transport and reducing the Urban Heat Island effect. There are currently no water or energy saving requirements for people installing swimming pools under 40kL in size, and this should be addressed either at a local or state government level.

Councils can *encourage* better performance, and can include guidelines for improving design to meet hotter climates, such as shading, insulation and glazing performance. However, it is the responsibility of the architect / designer / developer / home owner to understand and employ these recommendations appropriately and successfully.

A potential role for local and state governments and utilities is to invest in education around how to keep housing cool through landscaping and external shading. Furthermore, maintenance of initiatives installed under BASIX, e.g. rainwater tanks ,will ensure that the technologies are being used optimally and the anticipated efficiencies such as potable water savings are being delivered.

5.8 ACTIONS ARISING AND RESPONSES TO THE STUDY

Further investigation and study is required in response to identification of key action areas and issues raised through the review and consideration of this research report. The research objectives addressed in this report are understood to form the first stage of a broader project, with future stages intending to develop possible policy and planning responses to the findings reported here.

Summary of recommendations:

Improvement to current regulatory tools i.e. BASIX and NatHERS

- Improve NatHERS tool with updated climate data, ideally a future climate file, for example 2030, to ensure buildings are built to withstand future climate conditions.
- Improve BASIX tool with updated climate data, for example the 2030 climate scenario, and review calculations.
- Review BASIX policy in light of NSW Government policy on net zero Carbon emissions e.g. gas/all electric homes
- Review BASIX targets e.g. strengthen BASIX Energy target for multi-unit buildings and review BASIX Water target for Detached/Attached, investigate if targets can be adjusted spatially to reflect different climates
- Identify design modifications for different building types to guide the Thermal Comfort policy setting in BASIX under future climate scenarios.
- Establish a monitoring & evaluation protocol that ensures that:
  - BASIX is reviewed and adapted every 3 years in line with NCC updates
  - utilities are required to monitor the energy/water consumption of BASIX dwellings to support robust data in BASIX
  - the BASIX methodology is published to allow for peer review
- Ensure that revenue from the BASIX SEPP is hypothecated for tool maintenance and enhancement

Considerations for local government:

- Develop DCP/LEP clauses to strengthen non-BASIX sustainability initiatives eg. Transport, urban heat island effect, rainwater tanks for pools < 40kL.
- Improve BASIX & NatHERS compliance through educational videos for built environment professionals
- Provide education to homeowners & tenants around water security e.g. rainwater tank maintenance, raingardens
- Provide education to existing homeowners & tenants around keeping your home cool e.g. external shading, shading with landscaping, resilient species etc.

That NSW Government considers and plans for:

- peak demand challenges for existing housing stock as the climate warms
- greenhouse gas impact of increased use of air conditioning/mechanical cooling for all homes
- greater water demand from the residential sector in a warmer climate, and the provision of alternative water supply e.g. recycled water to all Sydney residences

6 LIMITATIONS

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APPENDIX A

HOW FUTURE CLIMATE DATA WAS USED IN BASIX MODELLING

NARCliM data in BASIX modelling

November 2020

Planning, Industry & Environment

Introduction

This document is to outline how climate projection data from the NSW and ACT Regional Climate Modelling (NARCliM) is incorporated in the BASIX calculation algorithm to model the effects of projected climate changes to currently BASIX-compliant homes.

NARCliM climate projection data

NARCliM Project, a research partnership between the NSW and ACT governments and the Climate Change Research Centre at the University of NSW, has produced an ensemble of robust regional climate projections for south-eastern Australia. The projections have been generated from four global climate models (GCMs) dynamically downscaled by three regional climate models (RCMs)[1]. The combination of the GCMs and RCMs results in 12 variations of climate projection data.

The NARCliM project team at DPIE provided the climate projection data corresponding to the Bureau of Metrology (BOM) weather station at Sydney Airport[2] - located in NatHERS climate zone 56. The climate projection data provided includes the following fields:

Table 1 NARCliM climate projection data fields for BASIX modelling

Data field	Explanation
tasmax	Daily maximum temperature in degrees C
tasmin	Daily minimum temperature in degrees C
Tasmean	Daily mean temperature in degrees C, calculated as the average of the minimum and maximum temperatures above
pracc_fl	Daily precipitation in mm
potevpmean	Daily potential evapotranspiration in mm

Climate data used in BASIX modelling

BASIX incorporates climate data in a number of calculations of potable water consumption and energy consumption. Daily rainfall data, determined by the data from a given year from BOM database that matches the expected volume of water that a rainwater tank supplies[3], is used in the

[1] About NARCliM, Adapt NSW <https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/About-NARCliM>, accessed on 10 August 2020
[2] Climate statistics for Australian locations – Summary statistics SYDNEY AIRPORT AMO, Australian Bureau of Meterology < http://www.bom.gov.au/climate/averages/tables/cw_066037.shtml>, accessed on 04 November 2020
[3] Developing Rainfall Data for the BASIX Raintank Model, Institute for Sustainable Futures for the Department of Infrastructure, Planning and Natural Resources (DIPNR), March 2005

soil and water balance calculations to determine irrigation water demand and the water demand satisfied by rainwater tanks. Evaporation data is also based on BOM database but the exact year when the data was selected cannot be identified. The BASIX soil and water balance is calculated on a daily basis, but the evaporation data is provided in the algorithm as monthly average applied to every day in a given month.

Correction factors based on ambient temperatures are used to adjust the performance of air conditioners, and the heating and cooling loads from the thermal comfort section as they are carried forward to the energy section.

NARCliM Projection data used in BASIX modelling

As the NARCliM data has 12 variations of climate projection, the first step is to determine which of the variation is used for BASIX modelling.

NARCliM provides daily data on precipitation and BASIX is using daily rainfall data in its soil and water balance calculations. The 12 variations of daily precipitation (pracc_fl) projections from NARCliM are compared with the daily rainfall data applicable to the Sydney Airport in the BASIX algorithm. The aggregate monthly rainfall from one of the variations (CCCMA3.1_R3) in 2003 from NARCliM provides the closest match with the aggregate monthly data in the BASIX algorithm (Figure 1), which is also similar to the trend reported from the BOM website.

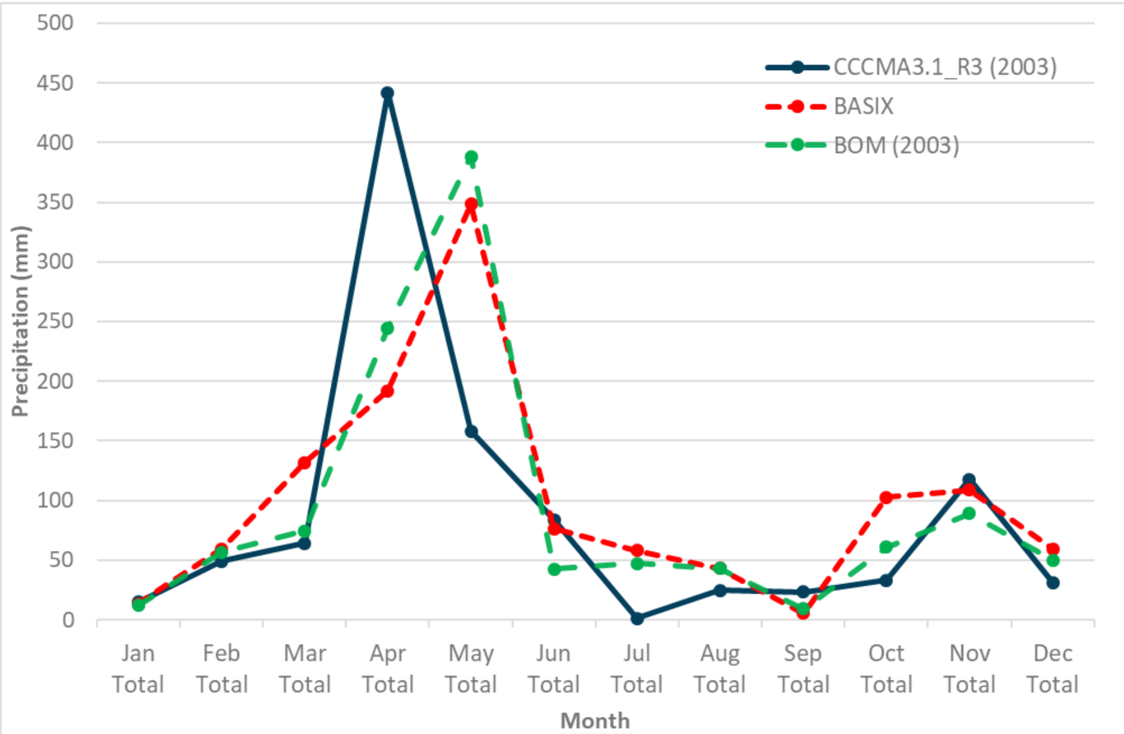


Figure 1 Comparison of aggregate monthly precipitation data between NARCliM

Updating BASIX data in the modelling algorithm

NARCliM climate projection data from the variation CCCMA3.1_R3 is used to update the data in the BASIX calculation algorithm for the modelling of currently BASIX-compliant homes. Since the NARCliM data provided is based on the weather station at Sydney Airport, data in the BASIX algorithm applicable to NatHERS climate zone 56 is updated.

- Rainfall – BASIX water section

Daily rainfall data is updated in the BASIX calculation algorithm for modelling in 2030 and 2070. Using Bondi (postcode 2026) as an example, a comparison of the aggregate monthly rainfall data currently used in the BASIX algorithm and the projected data for modelling in 2030 and 2070 is shown below:

Table 2 Aggregate monthly rainfall data used for BASIX modelling in 2030 and 2070 for postcode 2026

Month	**Monthly rainfall (mm)**		
	Current	2030	2070
Jan	52.20	7.68	64.76
Feb	156.30	37.75	55.35
Mar	107.80	102.05	59.60
Apr	191.00	175.96	60.66
May	415.50	49.45	280.12
Jun	86.30	15.89	205.29
Jul	24.40	8.25	92.14
Aug	37.00	8.75	25.08
Sep	9.40	6.82	42.23
Oct	73.50	83.50	136.08
Nov	112.80	32.84	75.37
Dec	49.90	37.79	56.76
Annual Total	**1316.10**	**566.71**	**1153.43**

- Evaporation – BASIX water section

Monthly averages of evaporation data are used for the daily water and soil balance calculations in BASIX.

The evaporation data is corrected with the “crop factors” to account for the effects of vegetation on potential evapo-transpiration. The “crop factors” used in BASIX have a value of less than 1, meaning that potential evapo-transpiration is less than the monthly evaporation data.

Daily potential evapo-transpiration data (and not evaporation data) is available from the NARCliM climate projections. The BASIX algorithm is adjusted to incorporate the NARCliM data directly for the water and soil balance calculations. Using again Bondi (postcode 2026) as an example, Table 3 compares the aggregate monthly BASIX evaporation data and the potential evapo-transpiration projection from NARCliM.

Table 3 Comparison of aggregate monthly BASIX evaporation data with the potential evapo-transpiration projection from NARCliM for postcode 2026

	Evaporation (mm)	**Potential evapo-transpiration (mm) (potevpmean)**		
Month	Current BASIX	2003 NARCliM	2030 NARCliM	2070 NARCliM
Jan	192.20	358.25	453.73	329.23
Feb	148.40	293.85	277.30	253.50
Mar	130.20	249.55	240.11	230.33
Apr	90.00	151.67	161.07	170.55
May	71.30	135.44	156.87	133.12
Jun	57.00	171.41	132.83	87.97
Jul	65.10	176.02	149.54	132.14
Aug	93.00	256.99	250.03	184.57
Sep	123.00	272.80	273.54	217.06
Oct	155.00	313.81	254.84	344.52
Nov	159.00	249.48	329.32	309.47
Dec	186.00	373.04	349.25	409.30

	Evaporation (mm)	Potential evapo-transpiration (mm) (potevpmean)		
Annual Total	**1470.20**	**3002.30**	**3028.43**	**2801.76**

- Hot water system temperature rises – BASIX energy section

Based on the NARCliM daily mean temperature data (tasmean), the average temperatures across 2003, 2030 and 2070 are shown in Table 4.

Table 4 Mean temperatures and temperature changes from hot water systems for BASIX modelling in 2030 and 2070

	2003	2030	2070
Yearly average of tasmean (degree C)	19.63	20.49	21.70
Difference from 2003	---	0.86	2.07
Temperature changes from hot water systems (degree C)	40 (current BASIX)	39.14	37.93

Assuming temperature projections affect the temperature of water inlet to hot water systems, temperature changes from the hot water systems are therefore corrected for BASIX modelling in 2030 and 2070. The corrected temperature changes are shown in Table 4.

- Heating and cooling correction factors – BASIX energy section

A number of correction factors are used in BASIX to calculate heating and cooling energy consumption. A correction factor varied with construction types is applied to the heating and cooling loads from the BASIX thermal comfort section, as they are carried forward as the heating and cooling demand in the energy section. The COP/EER of air conditioners are also corrected based on the geographic locations of the proposed dwelling due to variations of ambient temperatures.

The above correction factors are revised based on the heating and cooling thermostat settings used in the CheNath engine for NatHERS modelling[4], and the mean temperature (tasmean) projections in 2030 and 2070 from NARCliM.

[4] CheNath Repository, CSIRO Hstar portal <https://hstar.com.au/Home/Chenath>, accessed 04 November 2020

For example, the heating and cooling thermostat settings of dwellings located in Bondi (postcode 2026) – or NatHERS climate zone 56 are shown in Table 5.

The averages of daily mean temperature (tasmean) for days above the cooling thermostat temperature or below the heating thermostat temperature are evaluated. Differences of the averages in 2030 and 2070 to the average in 2003 are used to correct for the COP/EER of air conditioners as shown in Table 5.

Ratios of the averages in 2030 and 2070 to the average in 2003 are used to correct for the heating and cooling loads from the BASIX thermal comfort section as they are carried forward to the energy section.

Table 5 Changes of temperature projections for BASIX modelling in 2030 and 2070 for NatHERS climate zone 56

	2003	2030	2070
Cooling (thermostat temperature: 24.5 degree C)			
Average temperature of days above cooling thermostat temperature (degree C)	27.60	27.65	28.05
Difference from 2003 (degree C)	---	0.05	0.45
Ratio to 2003	---	1.002	1.016
Heating (thermostat temperature: 20 degree C[5])			
Average temperature of days below heating thermostat temperature (degree C)	15.58	15.81	16.49
Difference from 2003 (degree C)	---	0.23	0.91
Ratio to 2003	---	1.015	1.043

[5] Living spaces only

APPENDIX B

PLANS OF BASIX SAMPLE BUILDINGS

B1 BASIX SAMPLE DETACHED DWELLING BUILDING

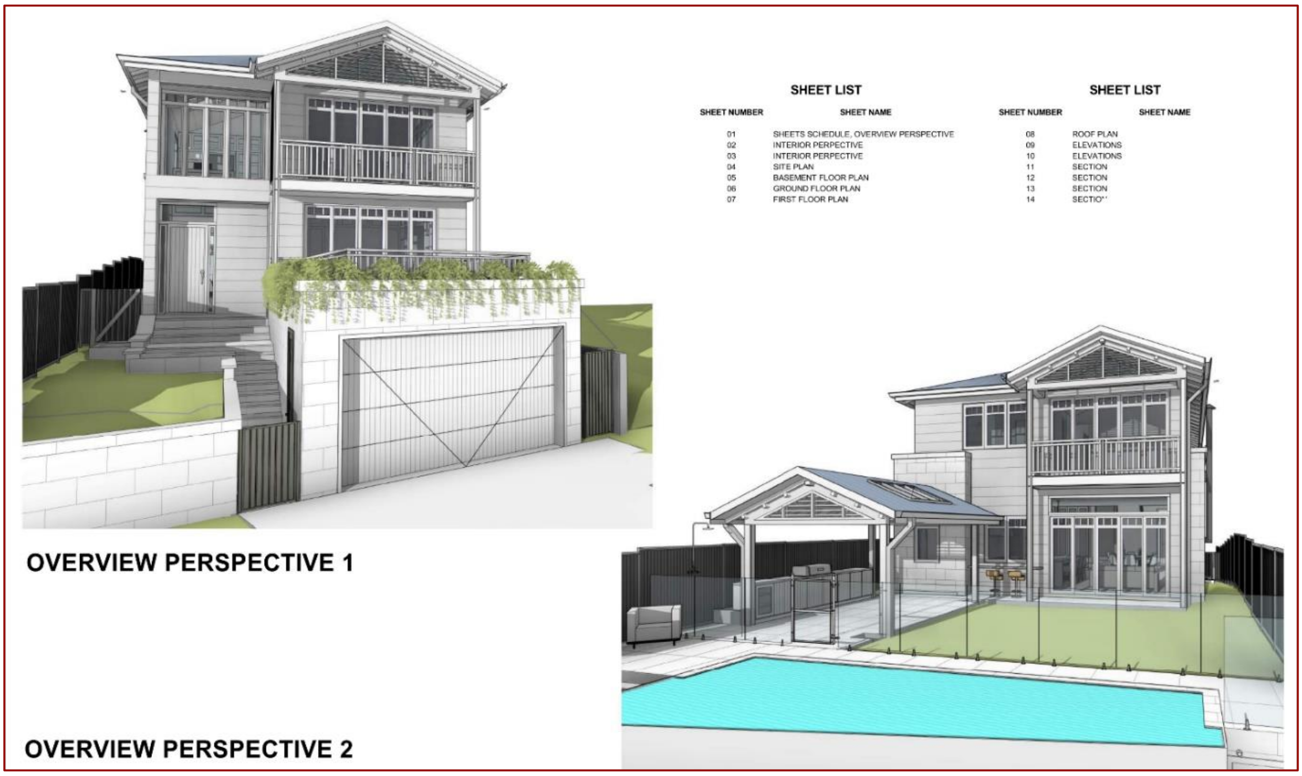


Figure B.1 BASIX sample Detached dwelling perspectives

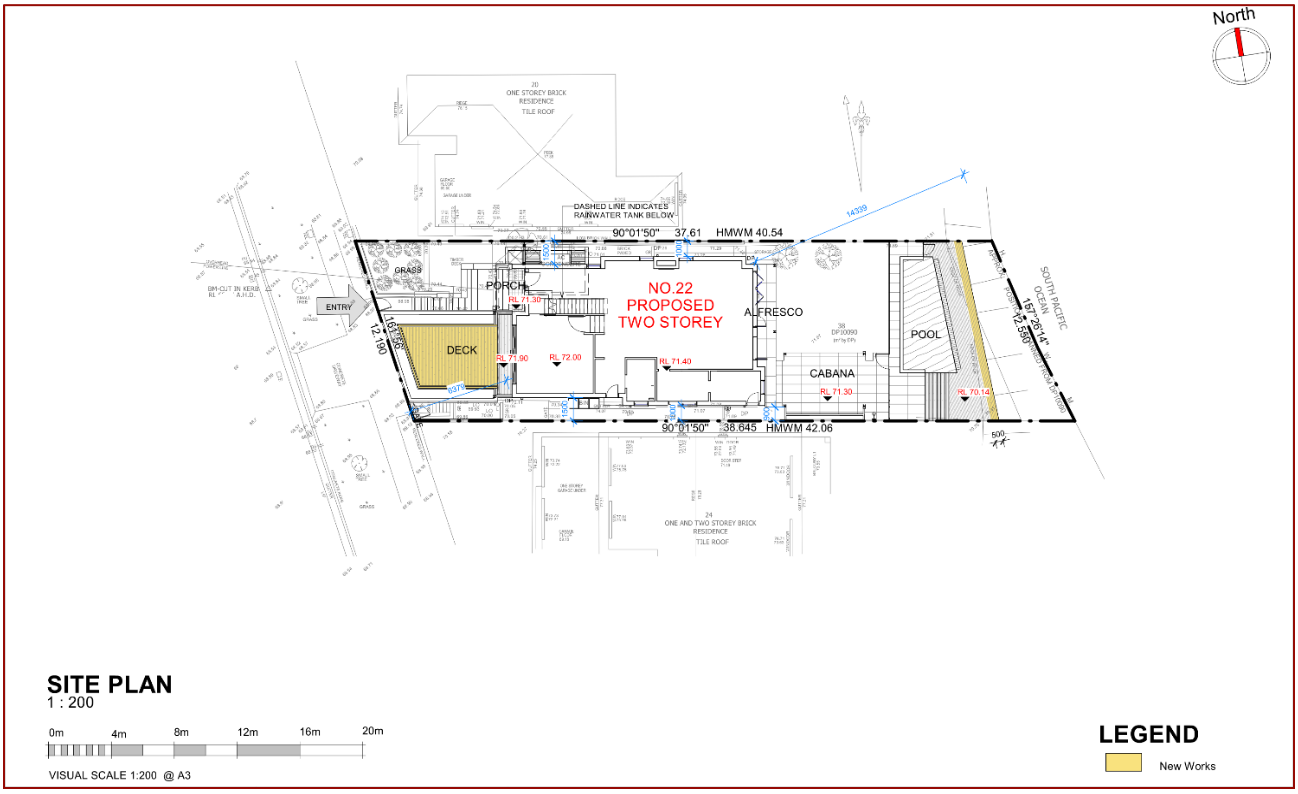


Figure B.2 BASIX sample Detached dwelling Site Plan

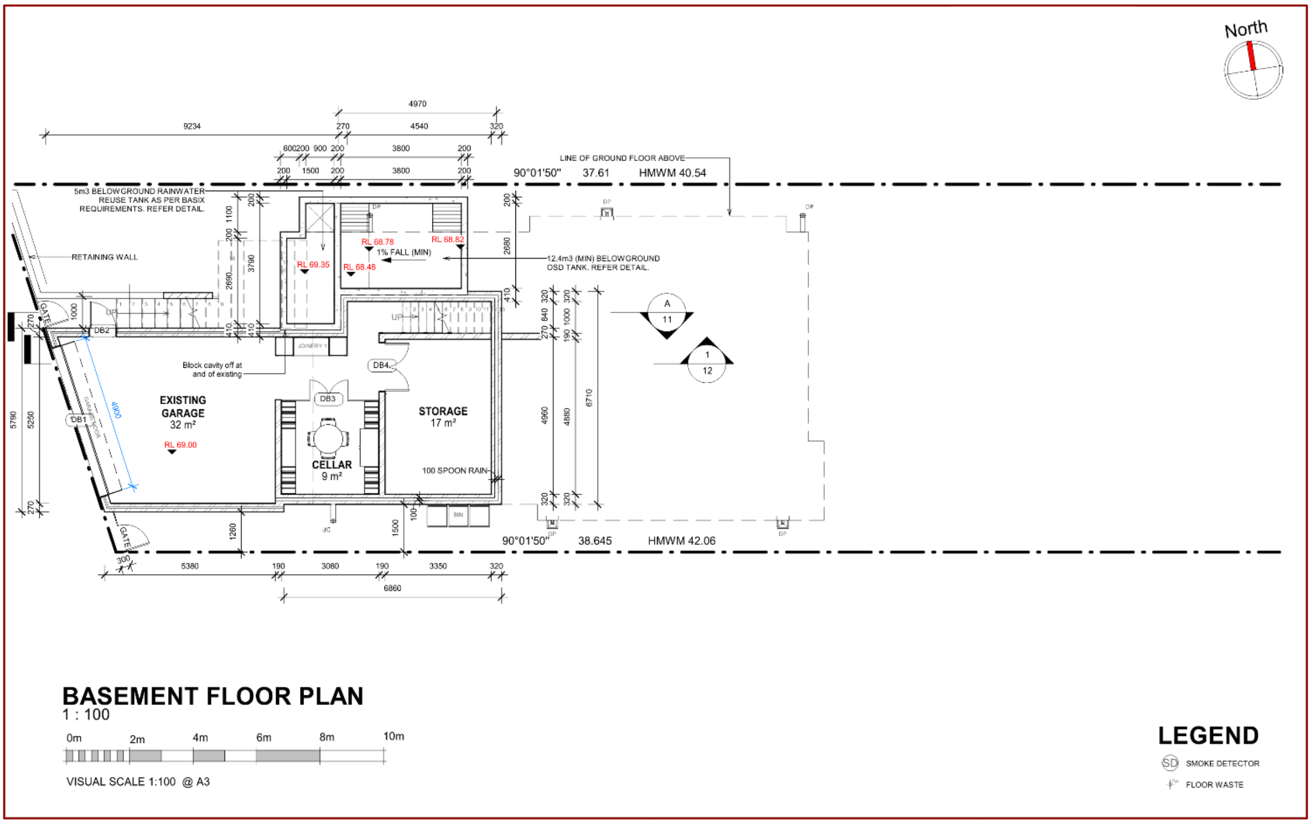


Figure B.3 BASIX sample Detached dwelling Basement Plan

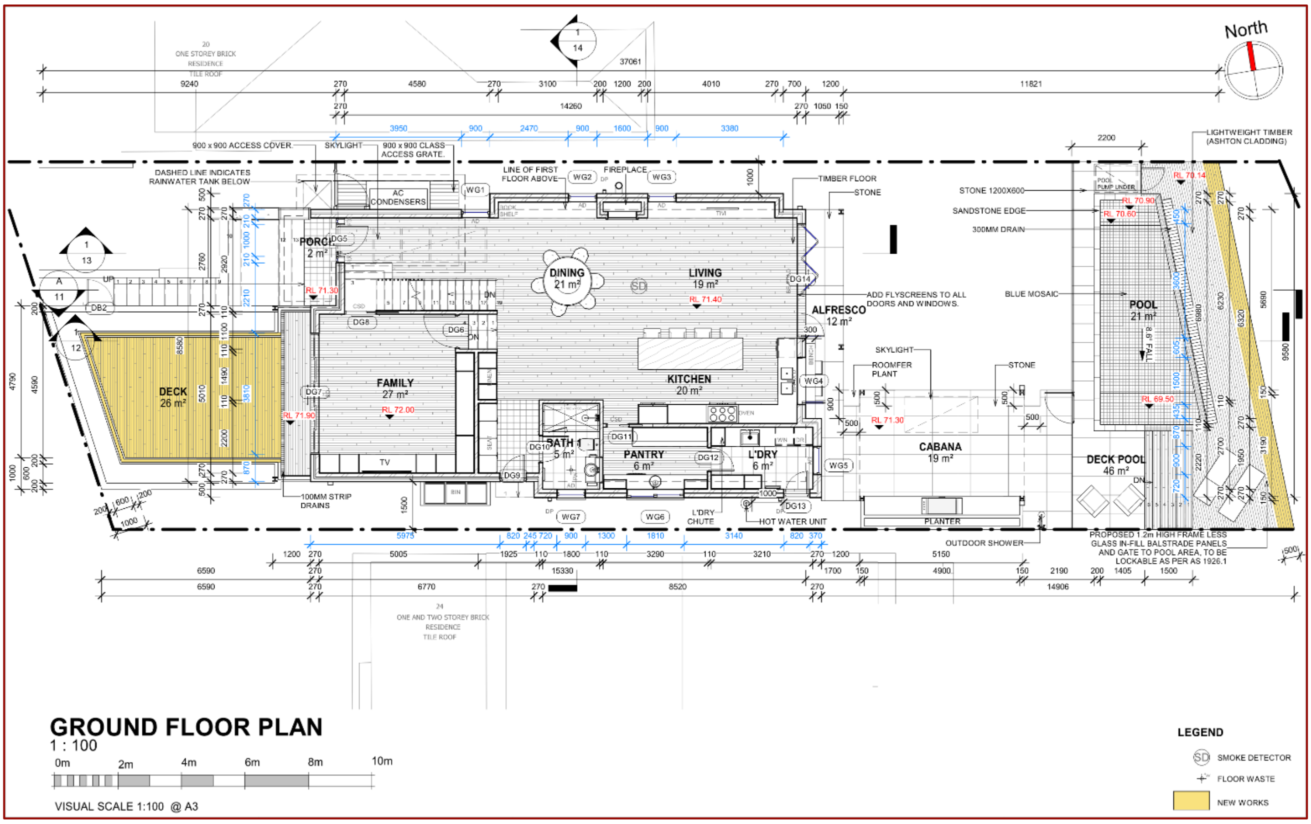


Figure B.4 BASIX sample Detached dwelling Ground Floor Plan

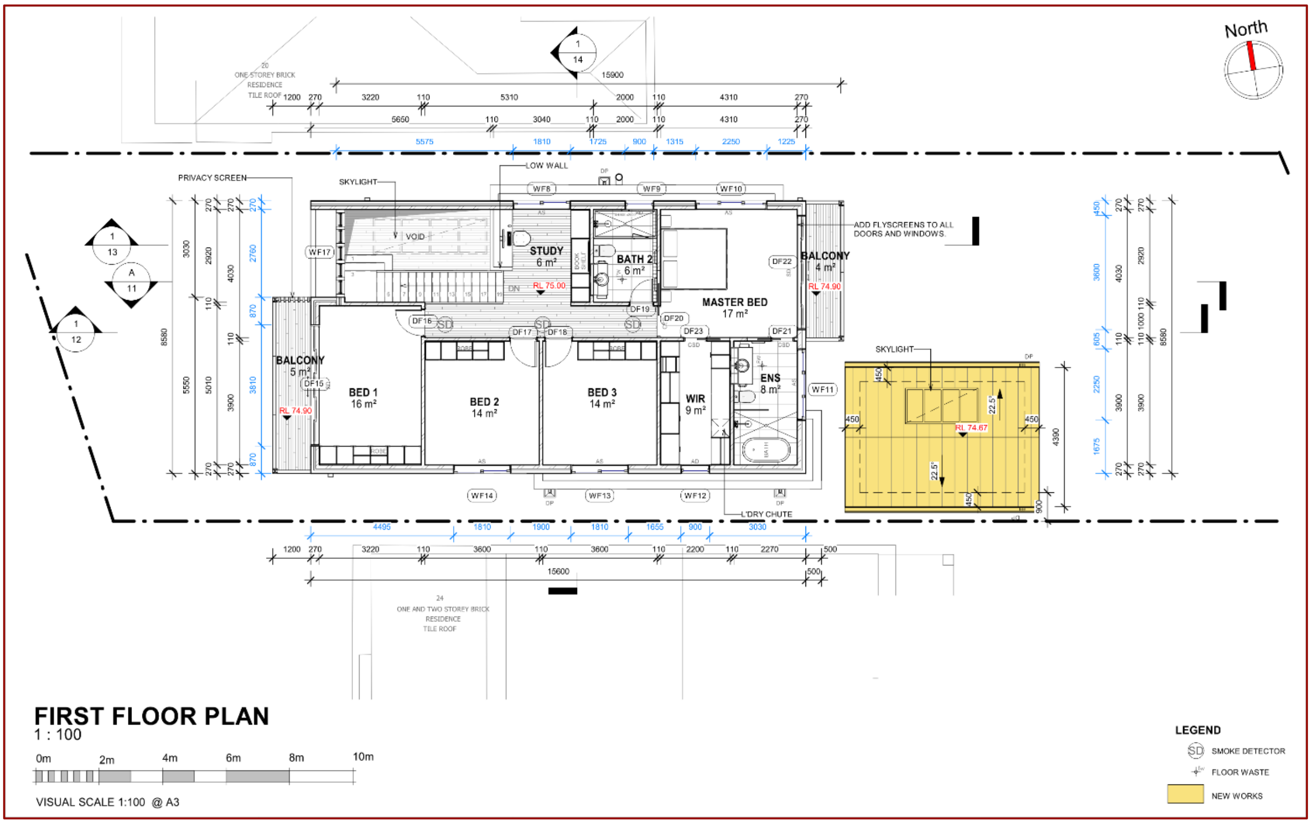


Figure B.5 BASIX sample Detached dwelling First Floor Plan

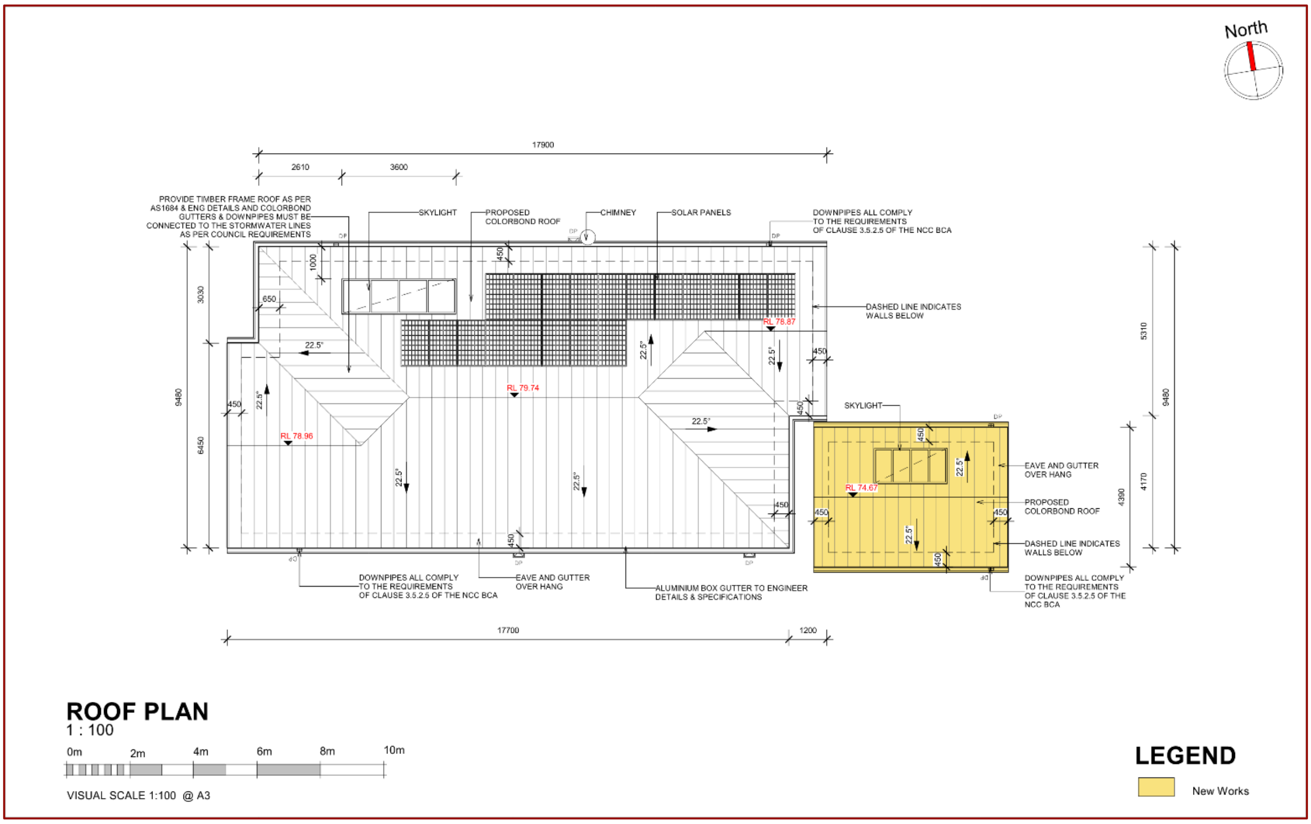


Figure B.6 BASIX sample Detached dwelling Roof Plan

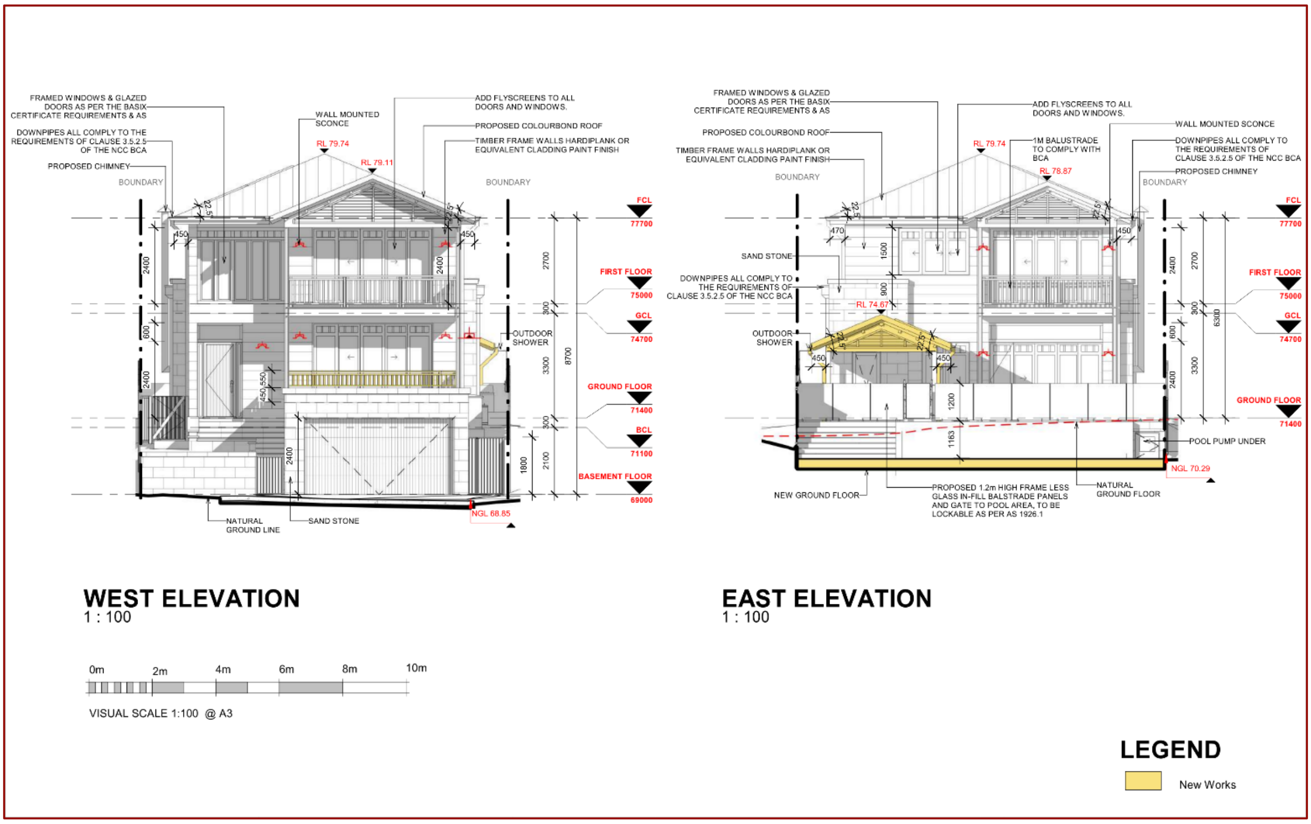


Figure B.7 BASIX sample Detached dwelling West & East Elevation

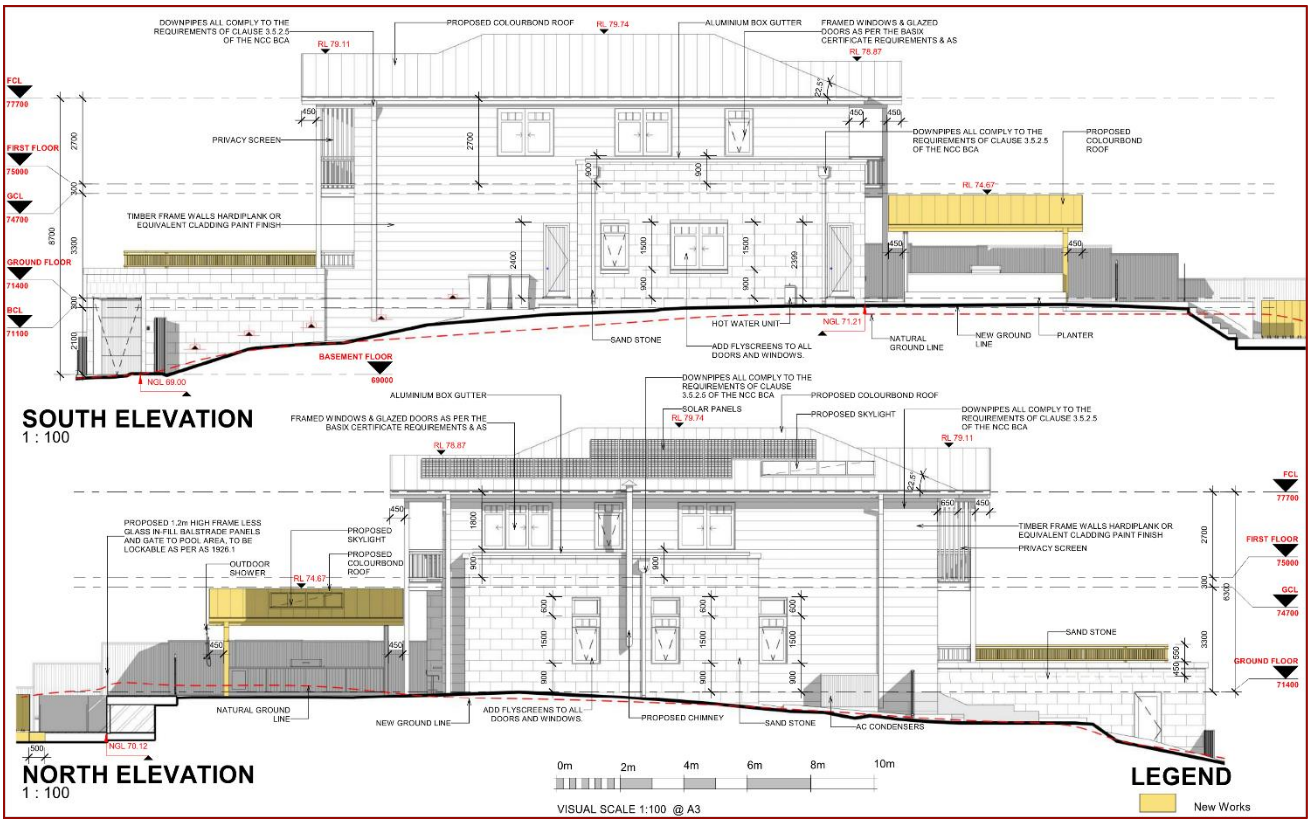


Figure B.8 BASIX sample Detached dwelling North & South Elevation

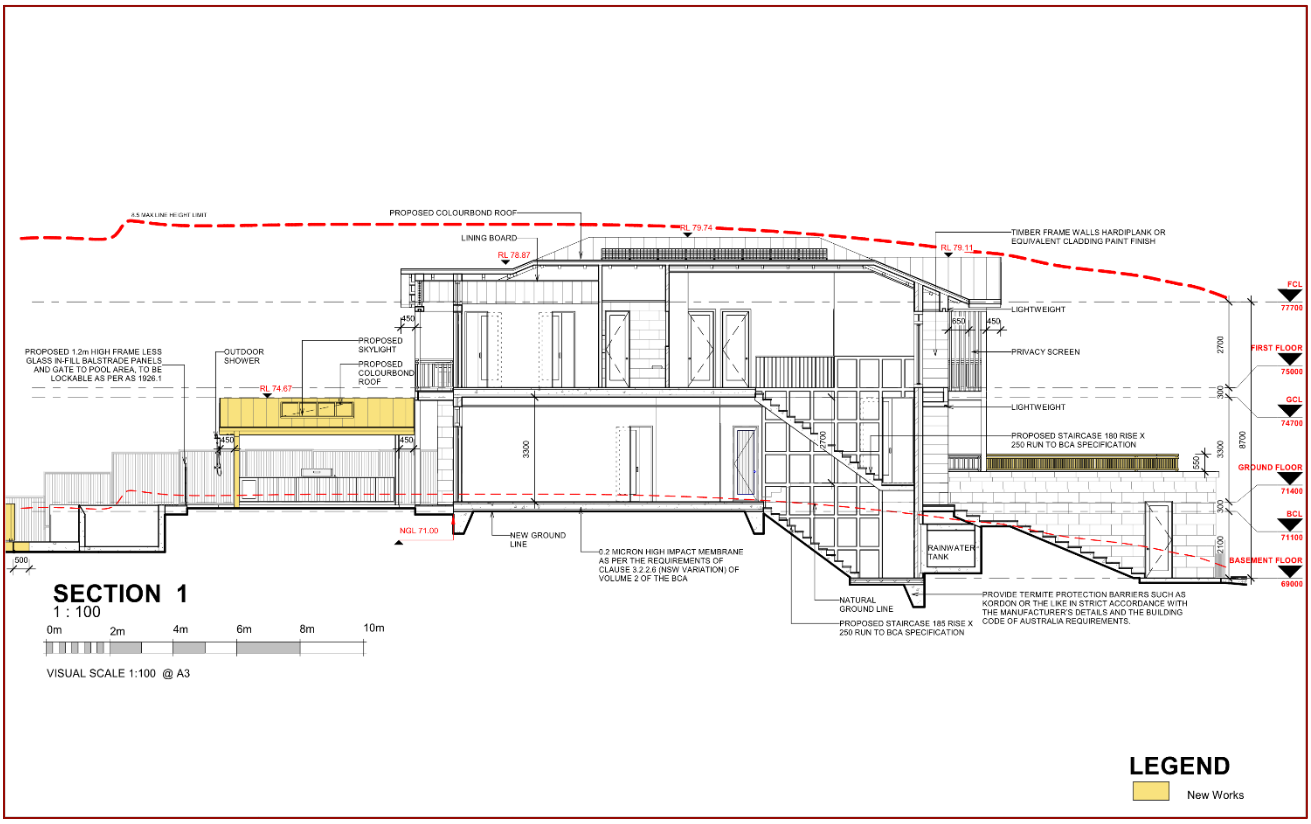


Figure B.9 BASIX sample Detached dwelling section

B2 BASIX SAMPLE ATTACHED DWELLINGS BUILDING

Figure B.10 BASIX Attached sample dwelling perspective

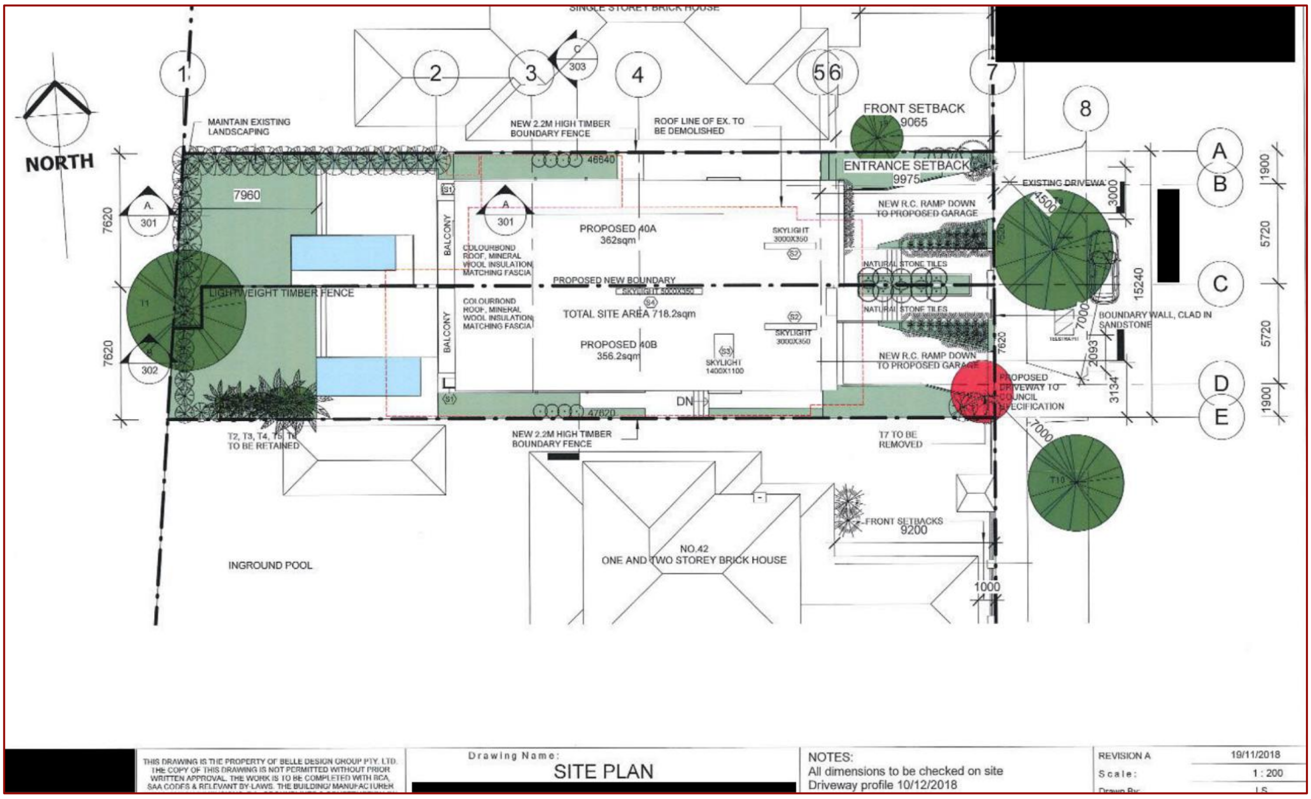


Figure B.11 BASIX Attached sample dwelling site plan

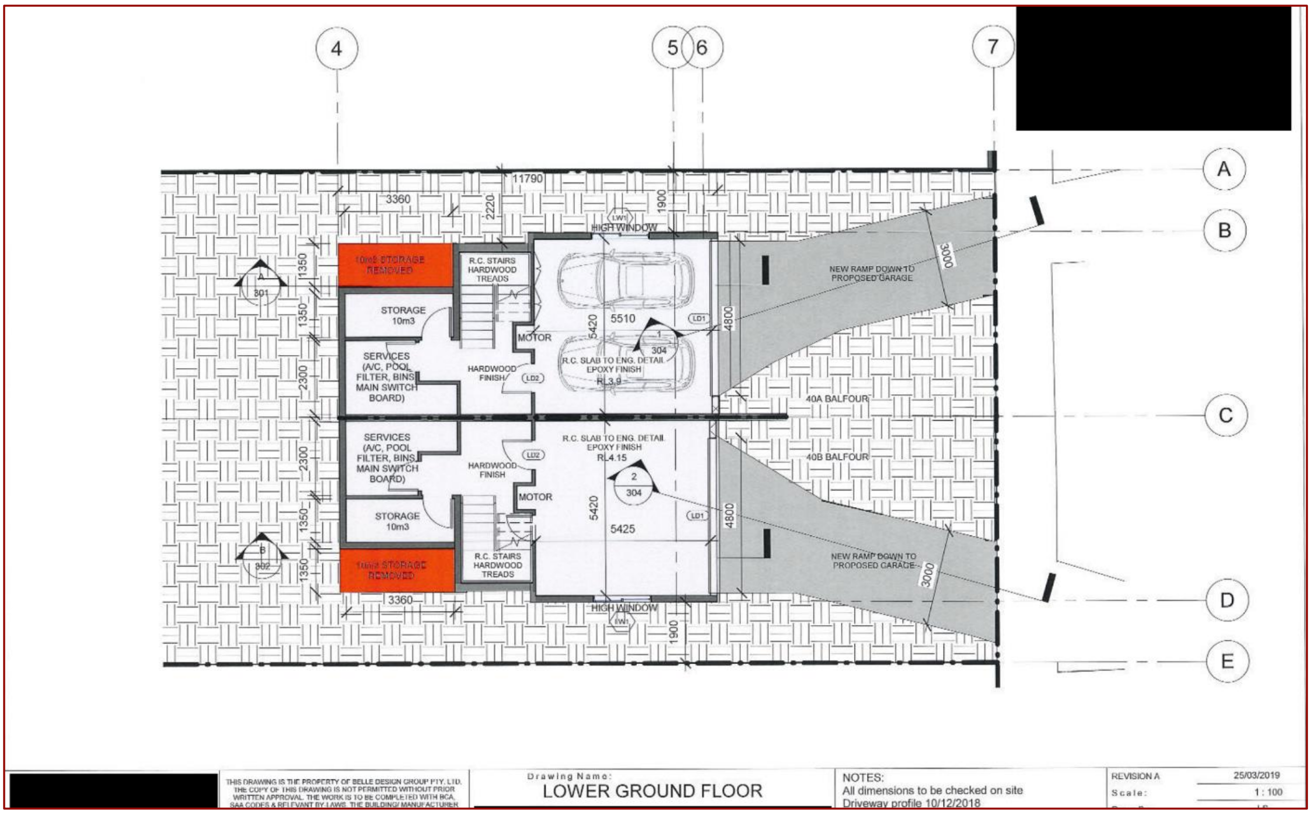


Figure B.12 BASIX Attached sample dwelling lower ground floor plan

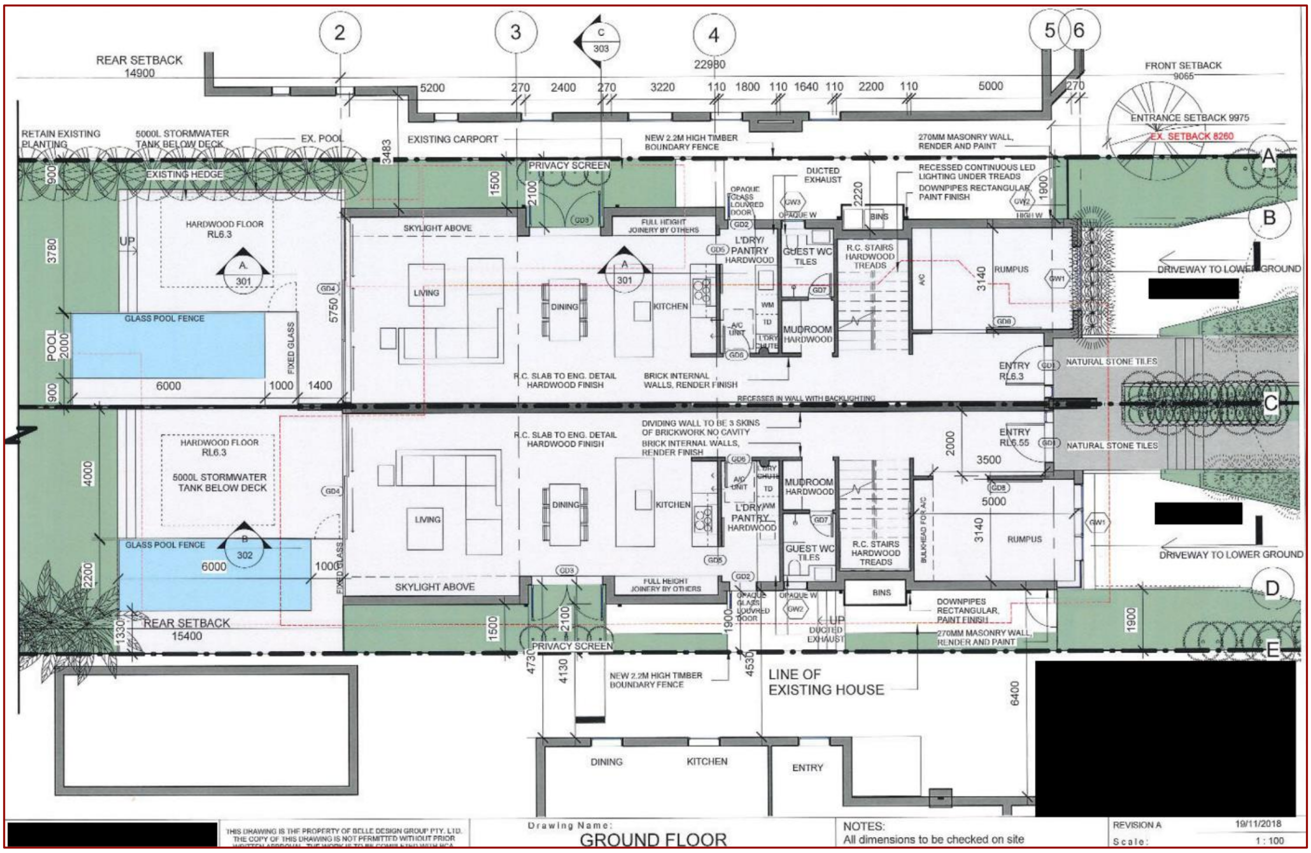


Figure B.13 BASIX Attached sample dwelling ground floor plan

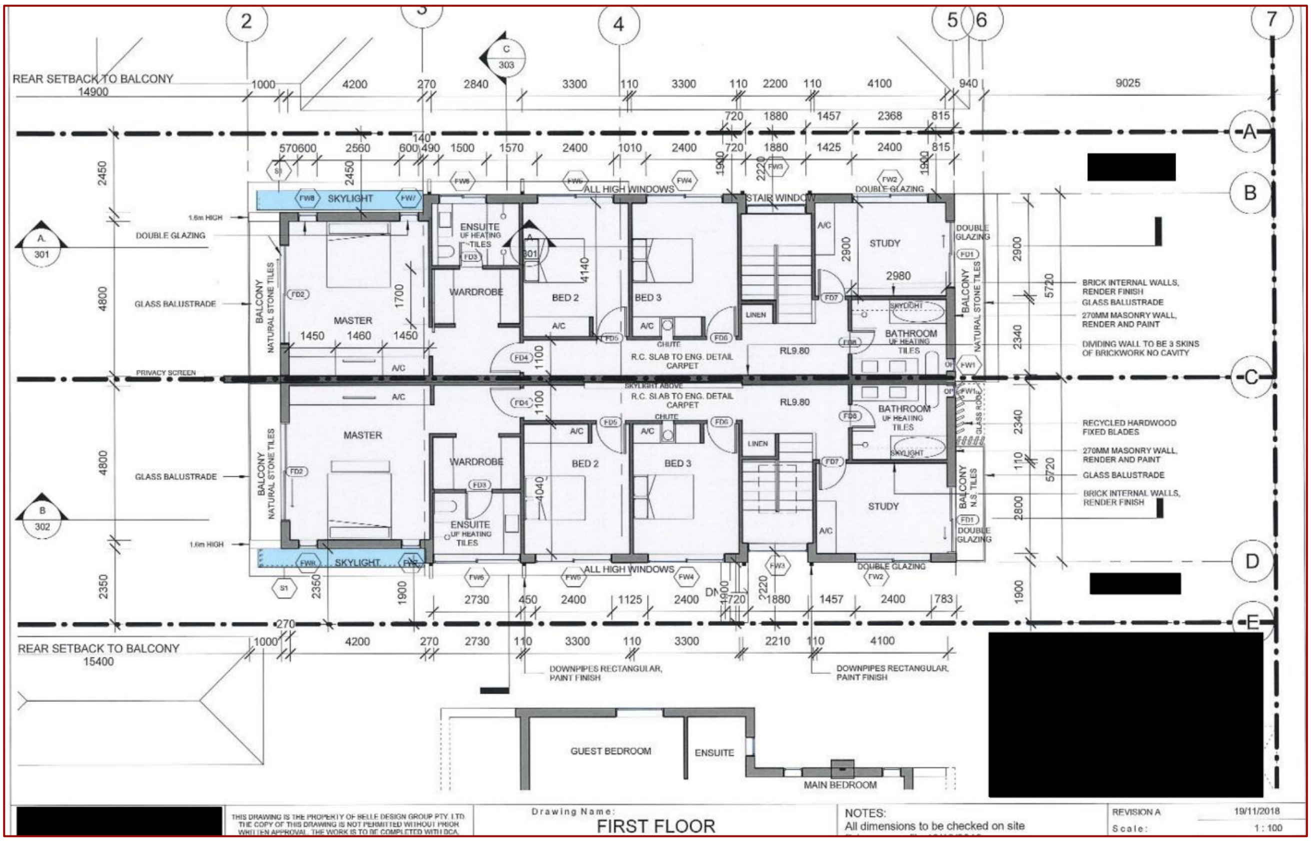


Figure B.14 BASIX Attached sample dwelling first floor plan

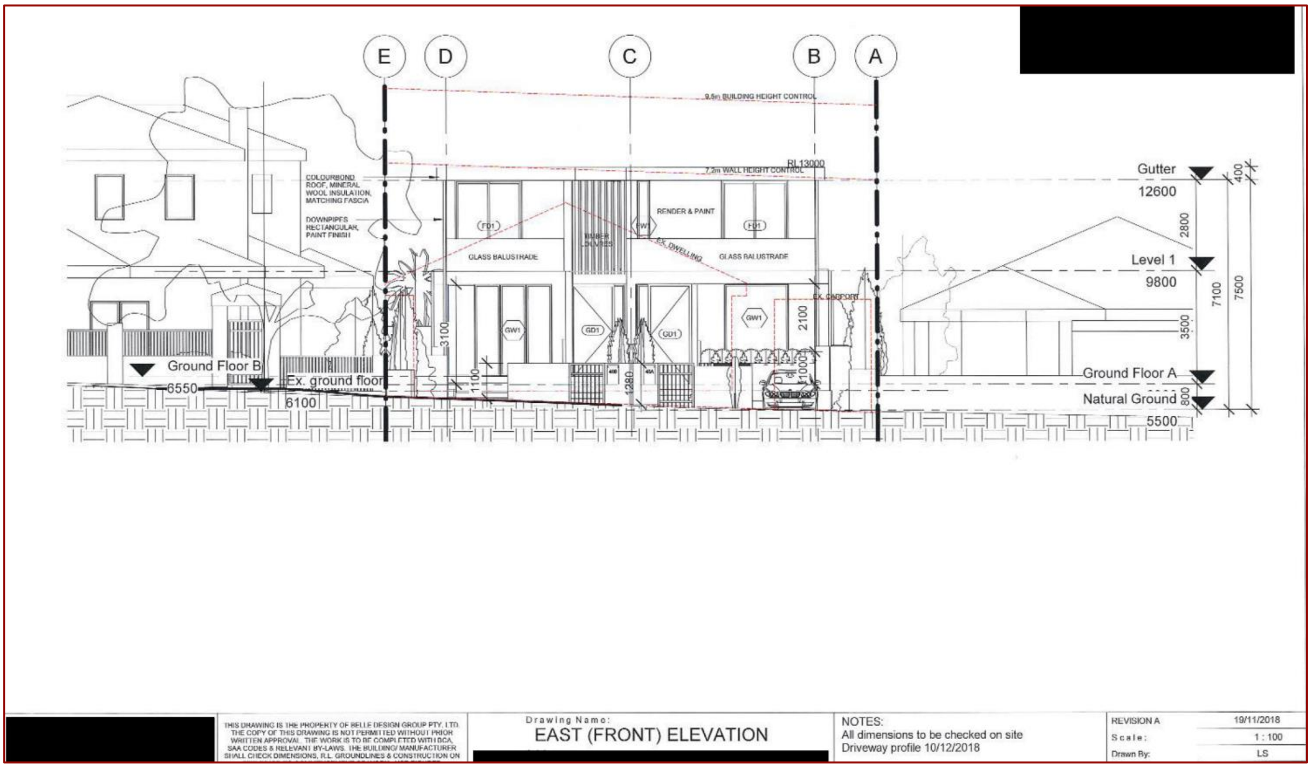


Figure B.15 BASIX Attached sample dwelling east elevation

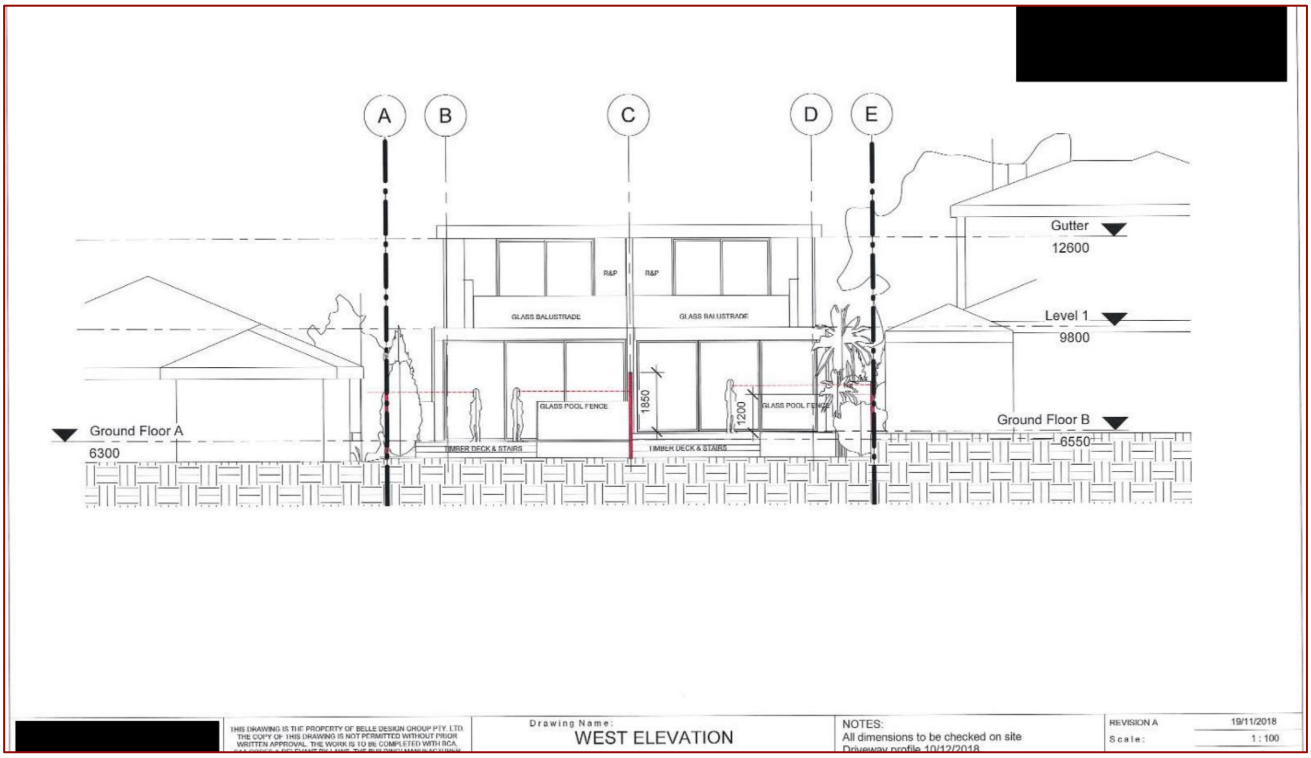


Figure B.16 BASIX Attached sample dwelling west elevation

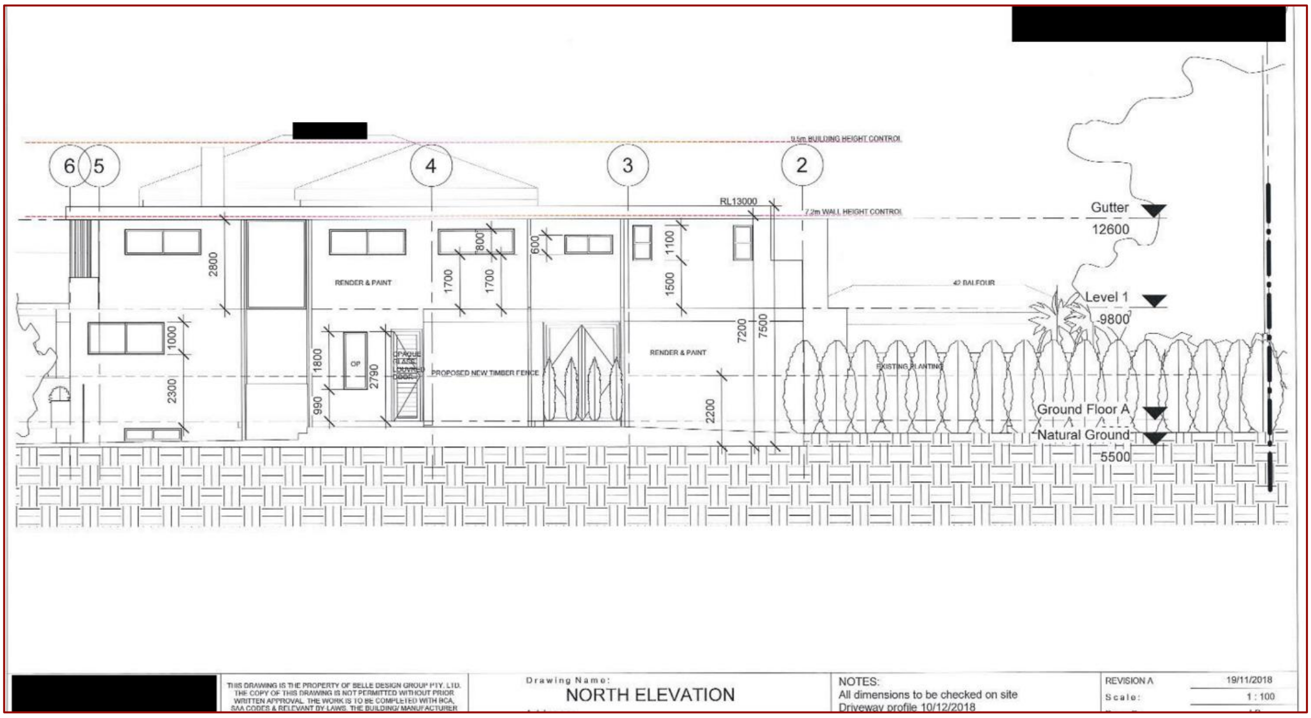


Figure B.17 BASIX Attached sample dwelling north elevation

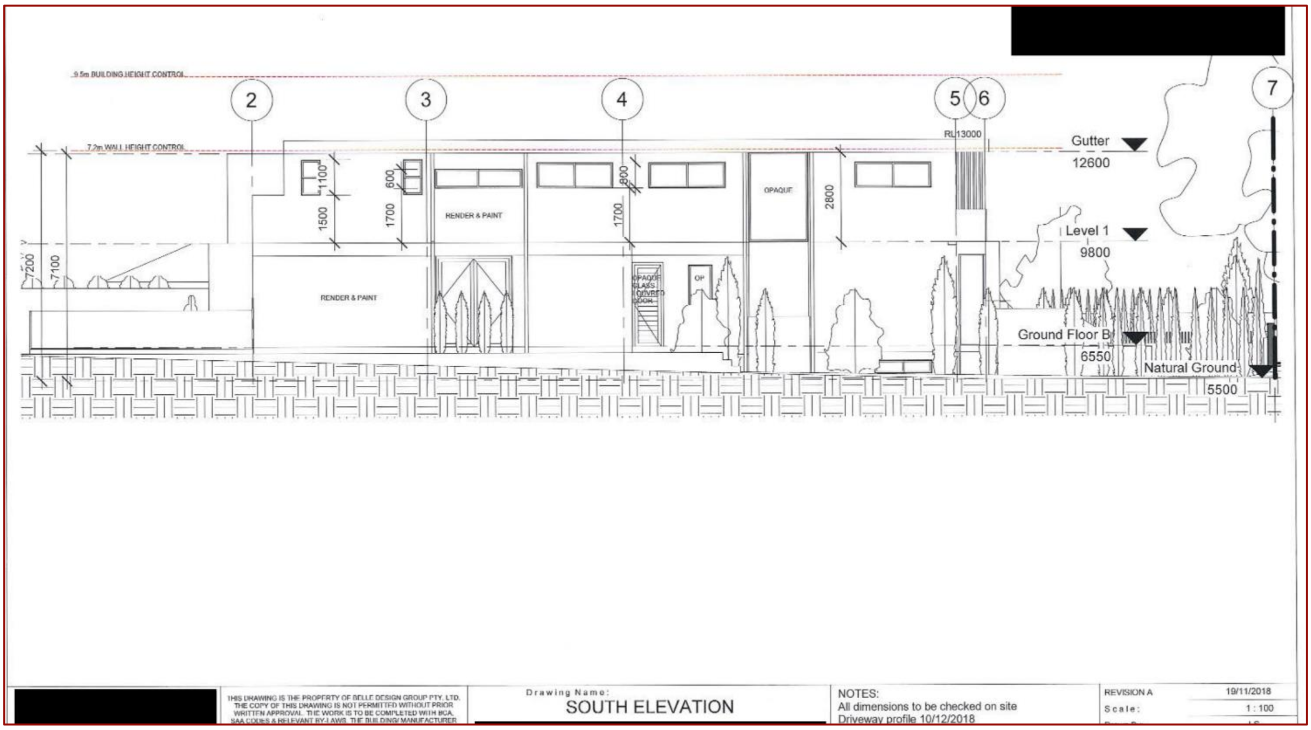


Figure B.18 BASIX Attached sample dwelling south elevation

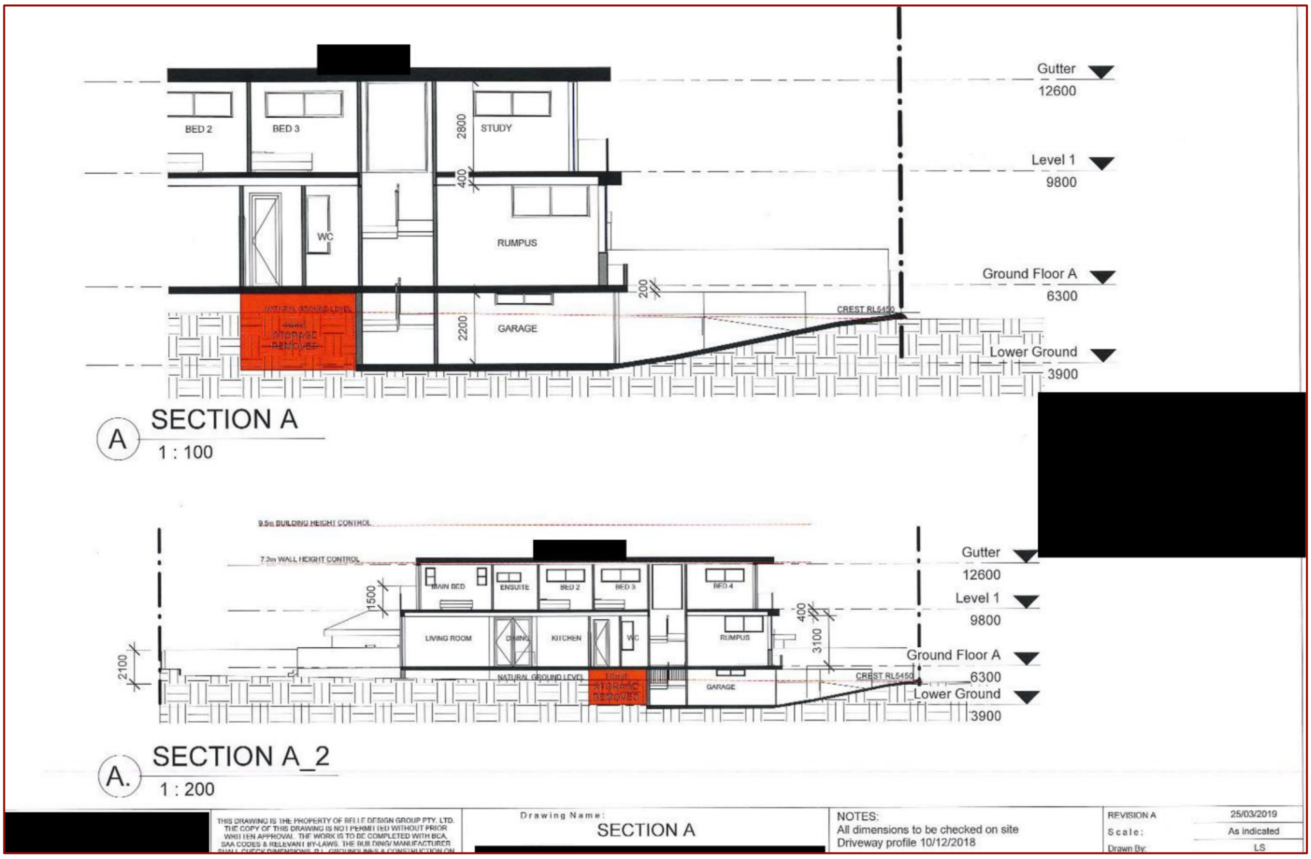


Figure B.19 BASIX Attached sample dwelling sections A and A2

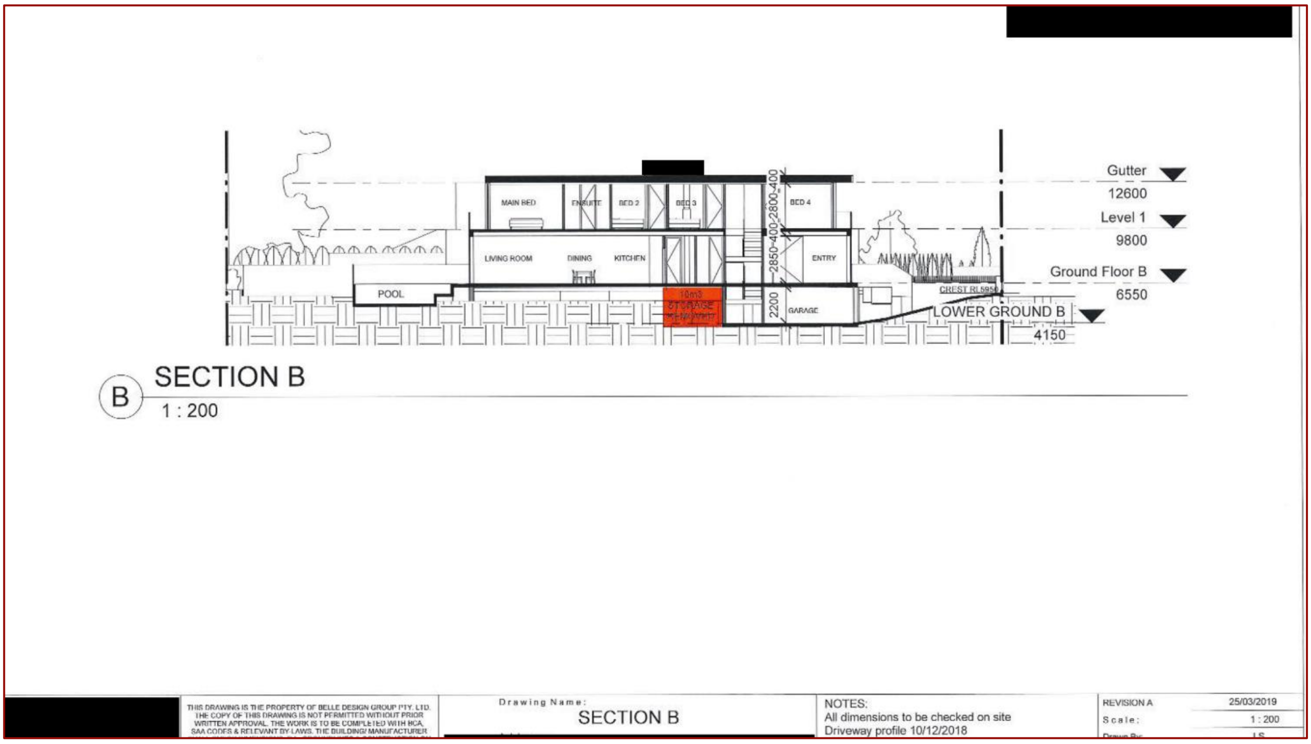


Figure B.20 BASIX Attached sample dwelling section B

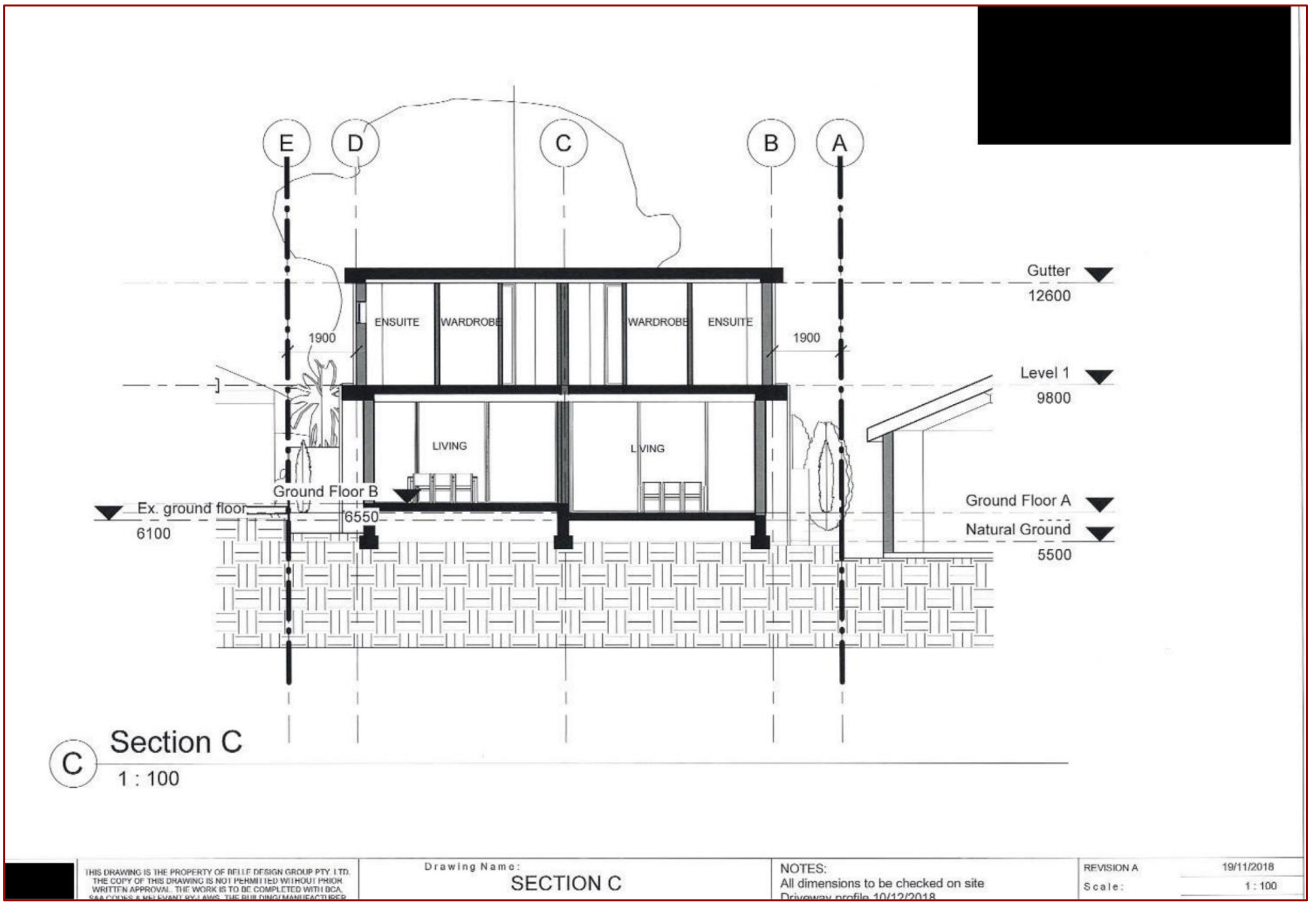


Figure B.21 BASIX Attached sample dwelling section C

B3 BASIX SAMPLE LOW-RISE BUILDING

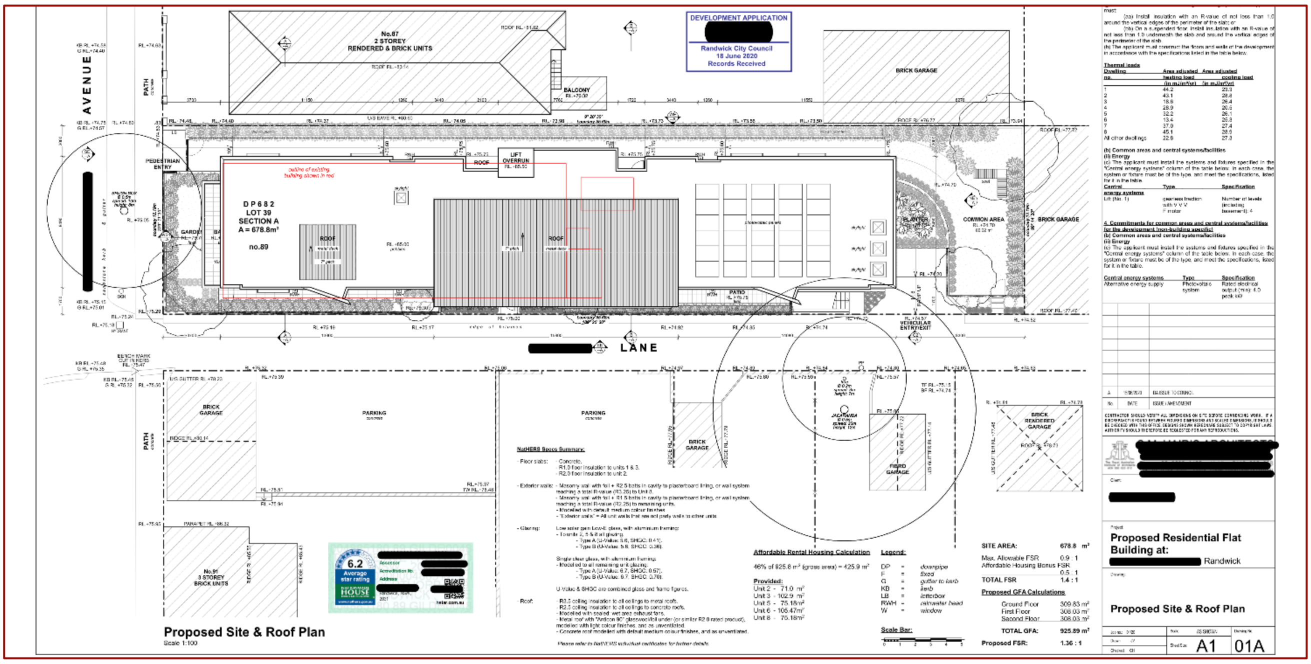


Figure B.22 BASIX Low-rise sample building site & roof plan

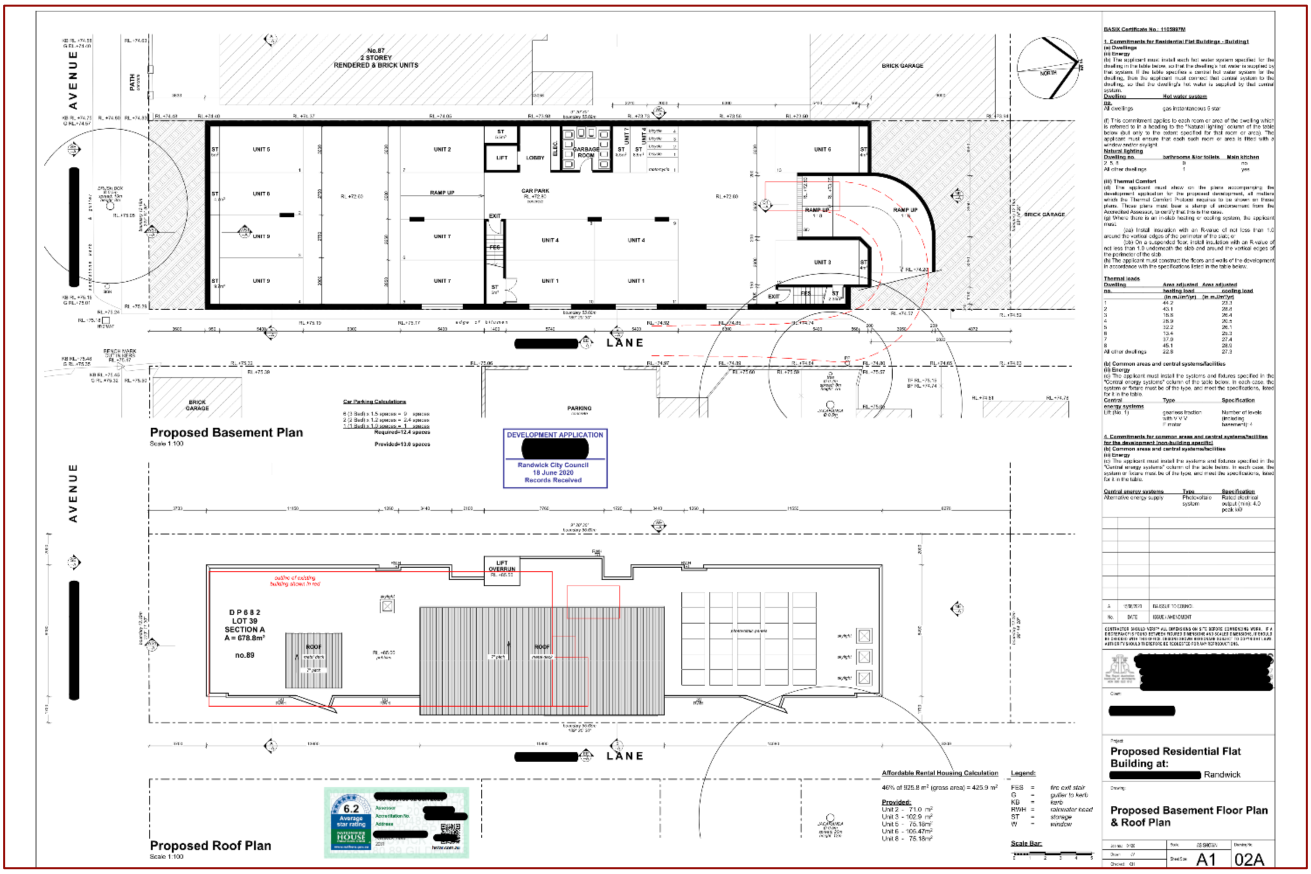


Figure B.23 BASIX Low-rise sample building basement & roof plan

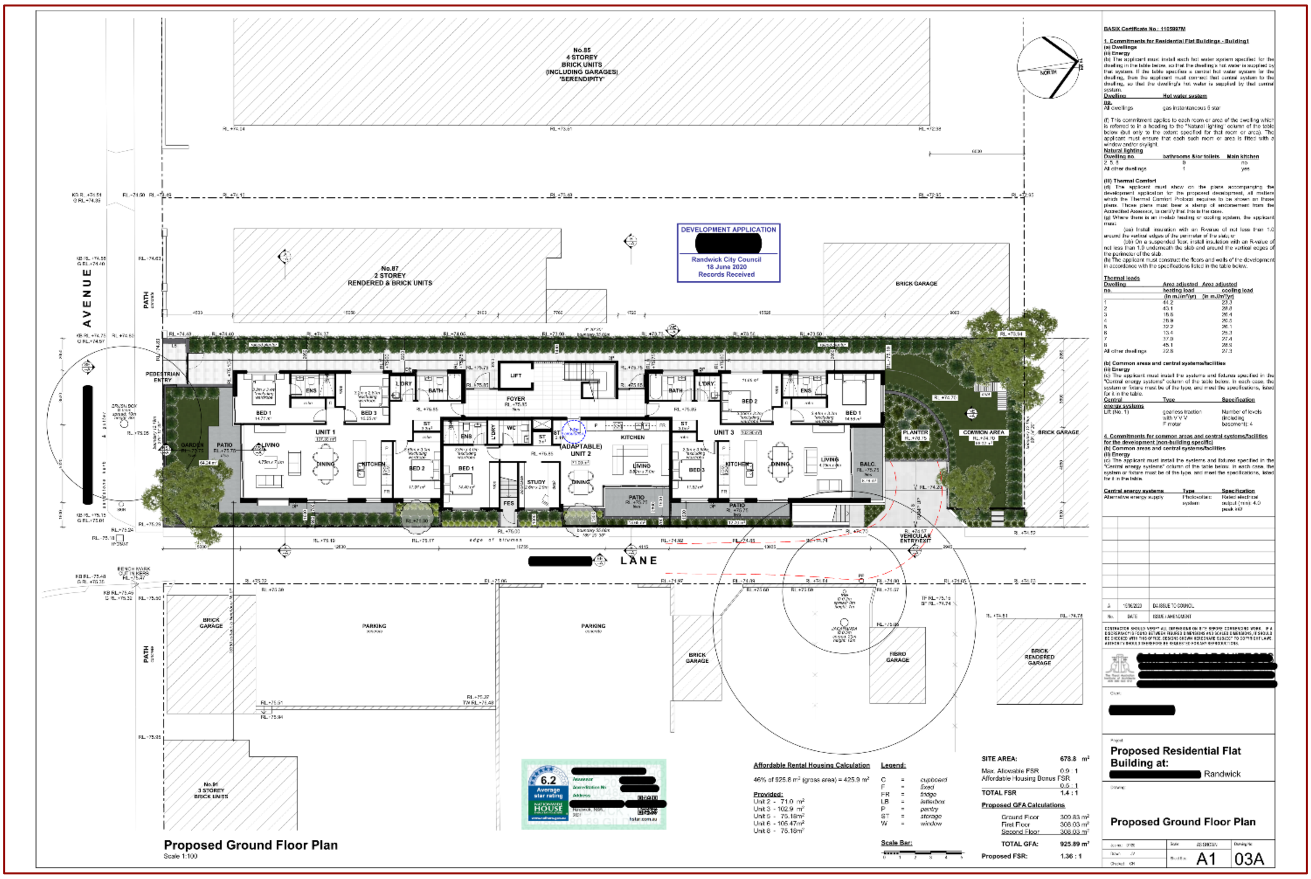


Figure B.24 BASIX Low-rise sample building ground floor plan

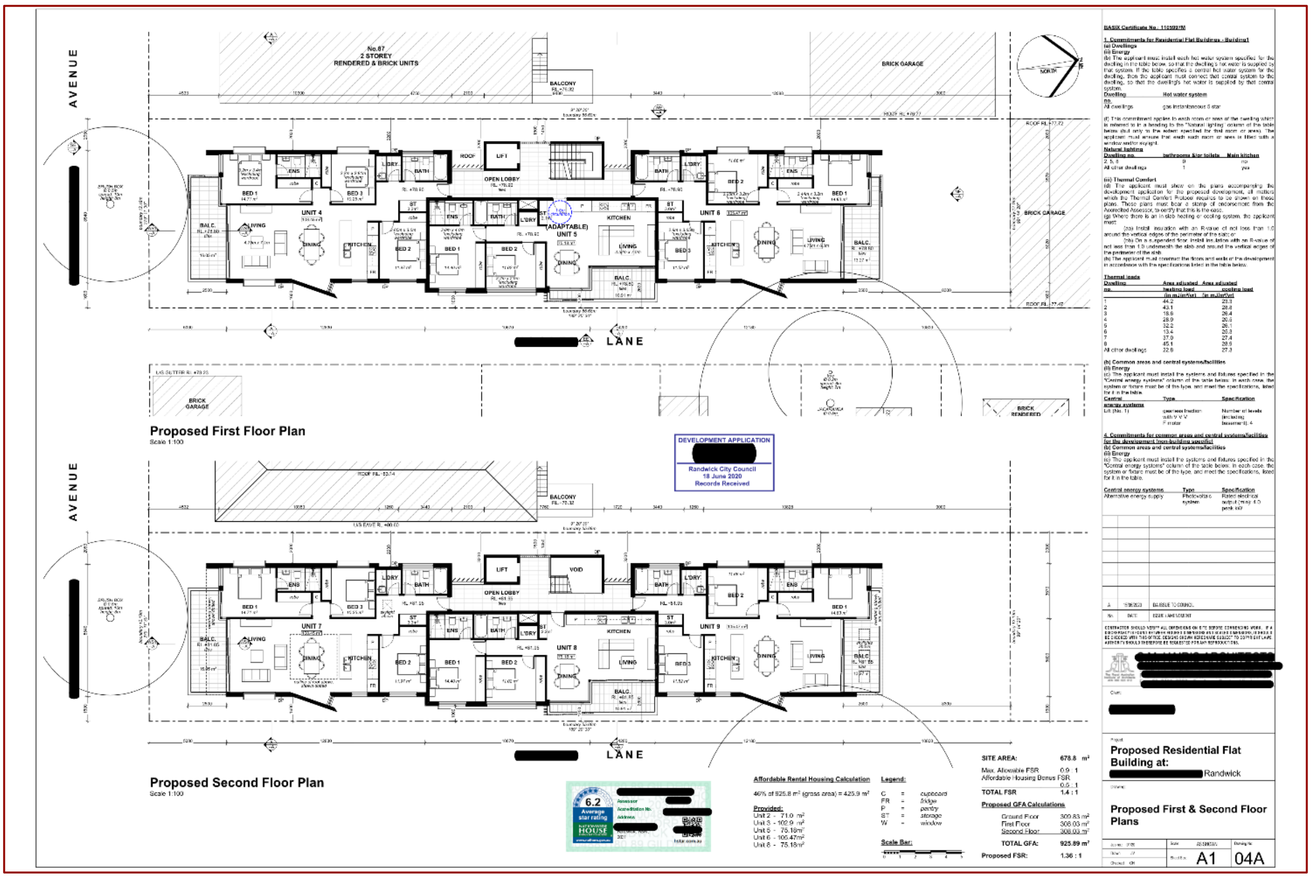


Figure B.25 BASIX Low-rise sample building first and second floor plans

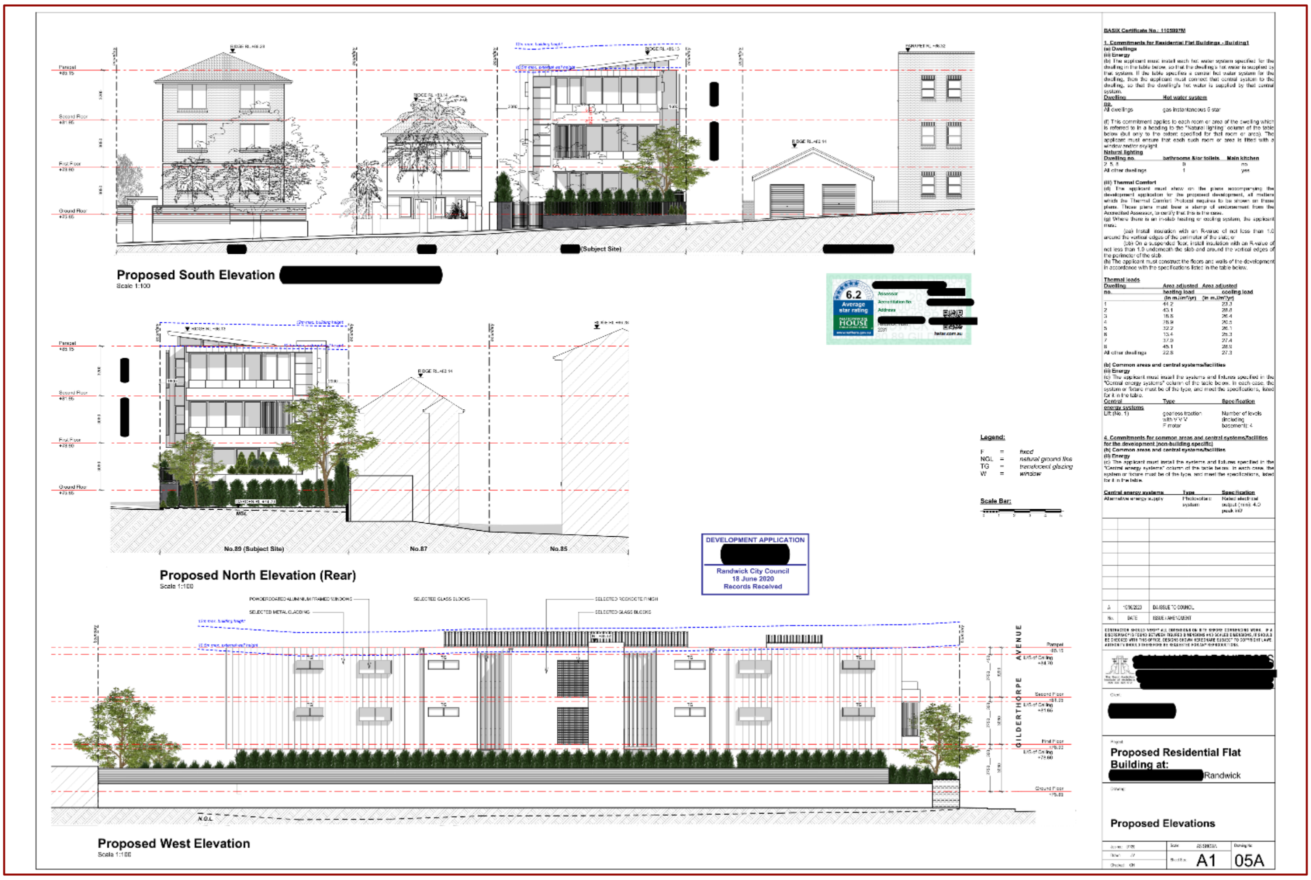


Figure B.26 BASIX Low-rise sample building elevations

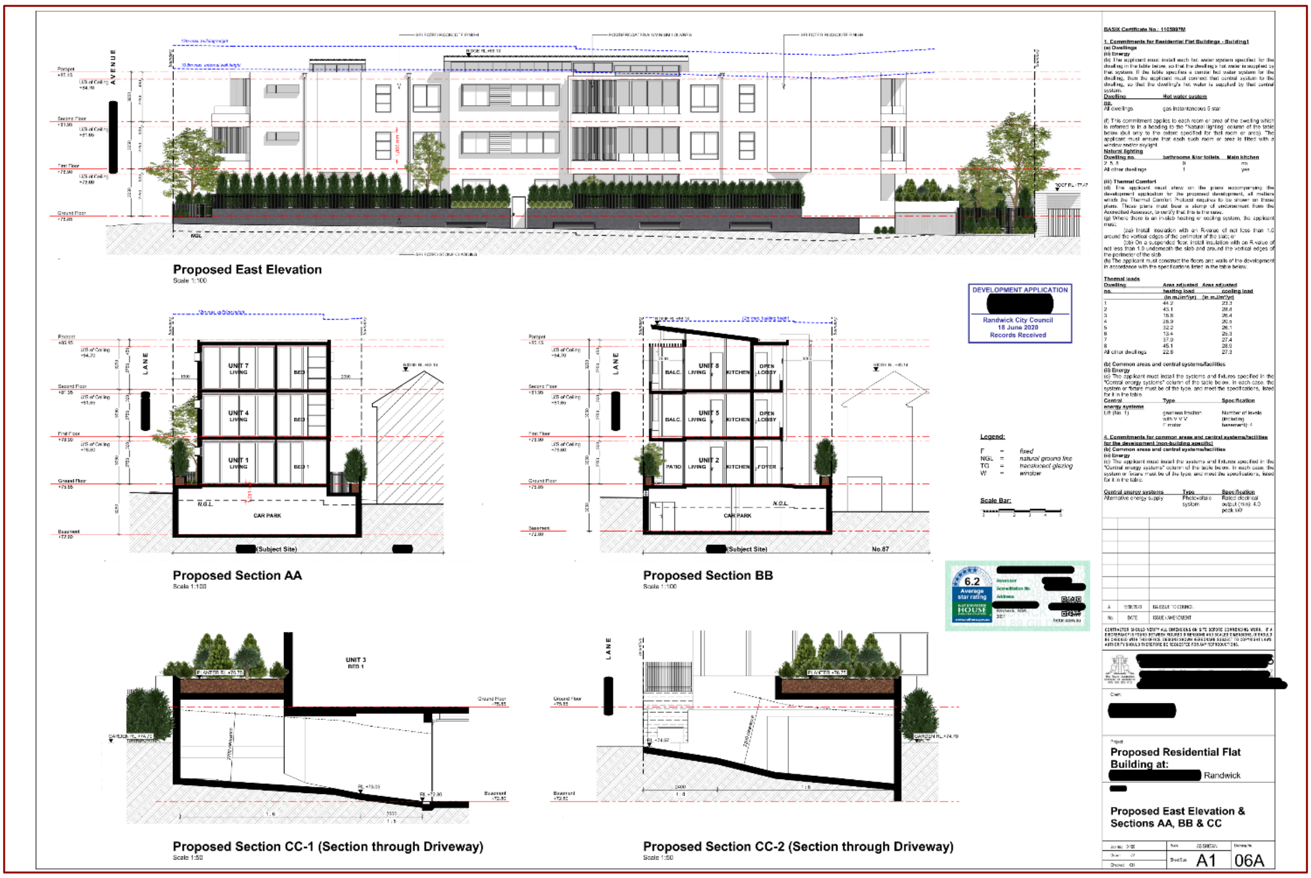


Figure B.27 BASIX Low-rise sample building sections

B4 BASIX SAMPLE MID-RISE BUILDING

Figure B.28 BASIX Mid-rise sample building photomontage

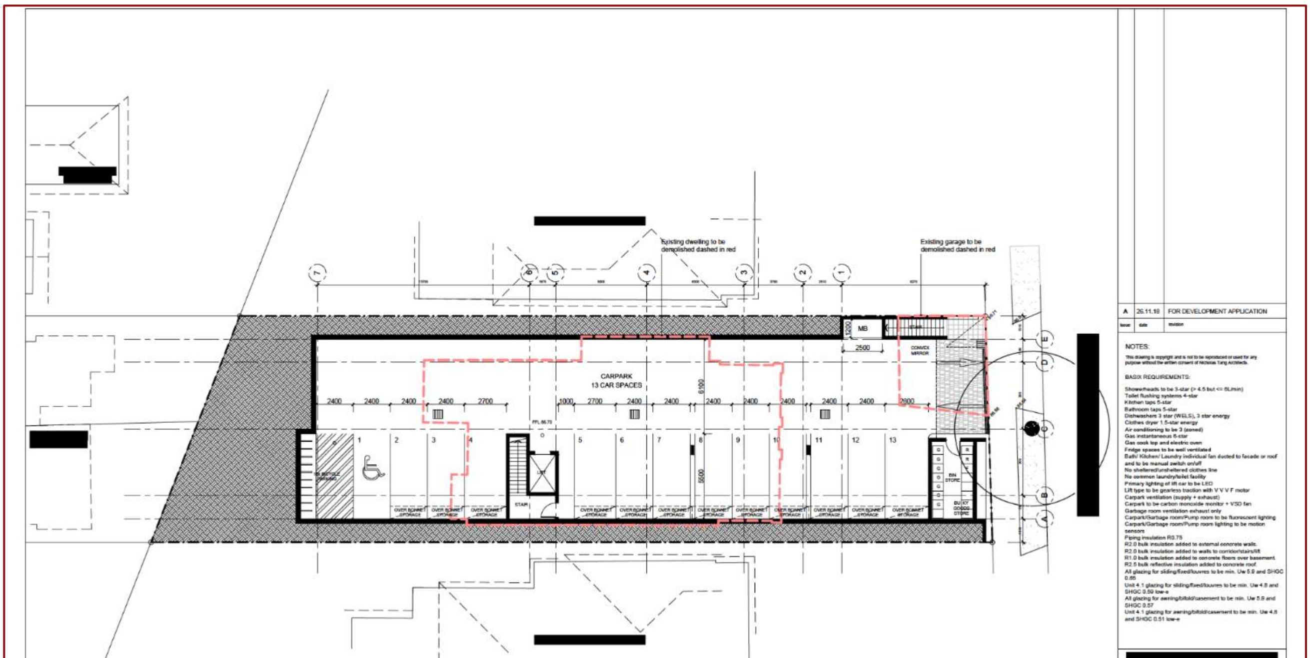


Figure B.29 BASIX Mid-rise sample building basement plan

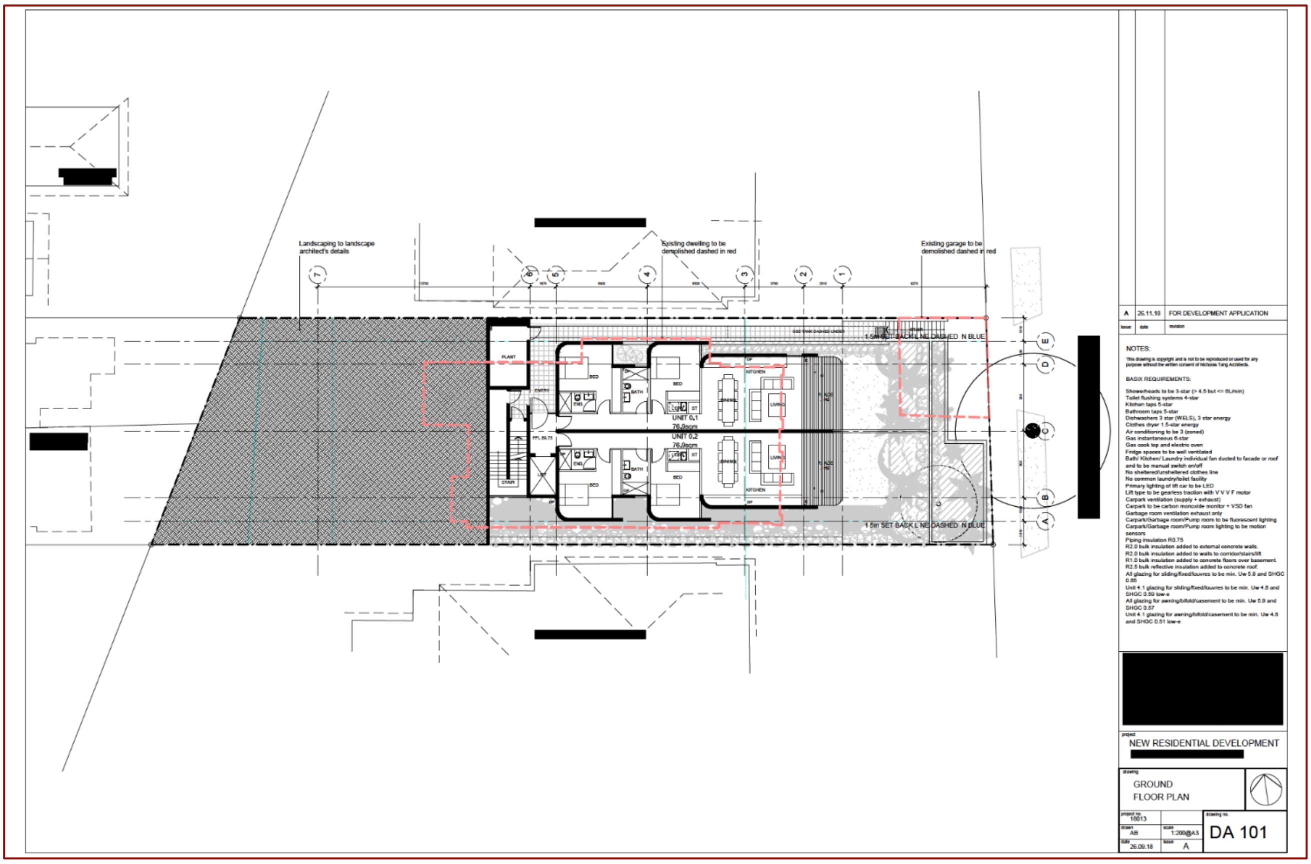


Figure B.30 BASIX Mid-rise sample building ground floor plan

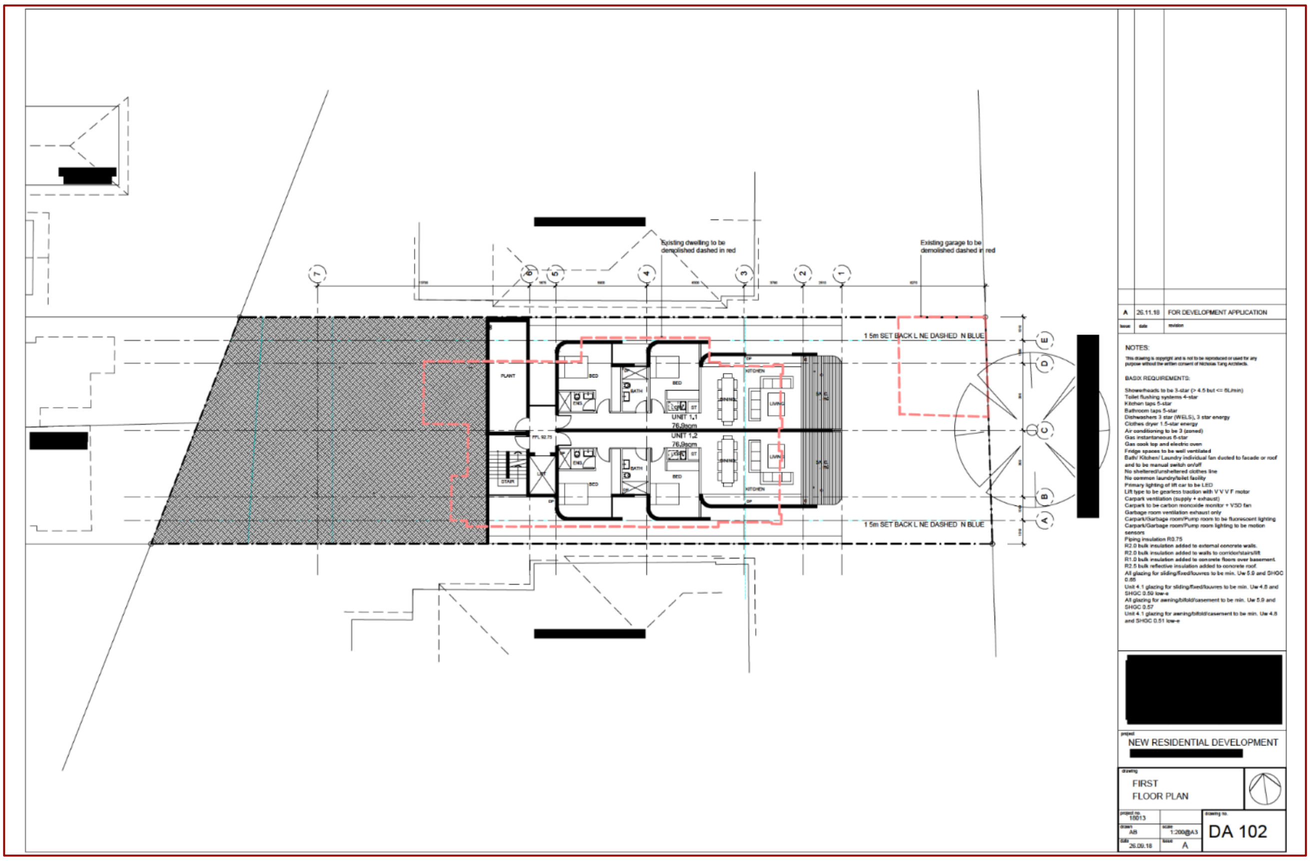


Figure B.31 BASIX Mid-rise sample building first floor plan

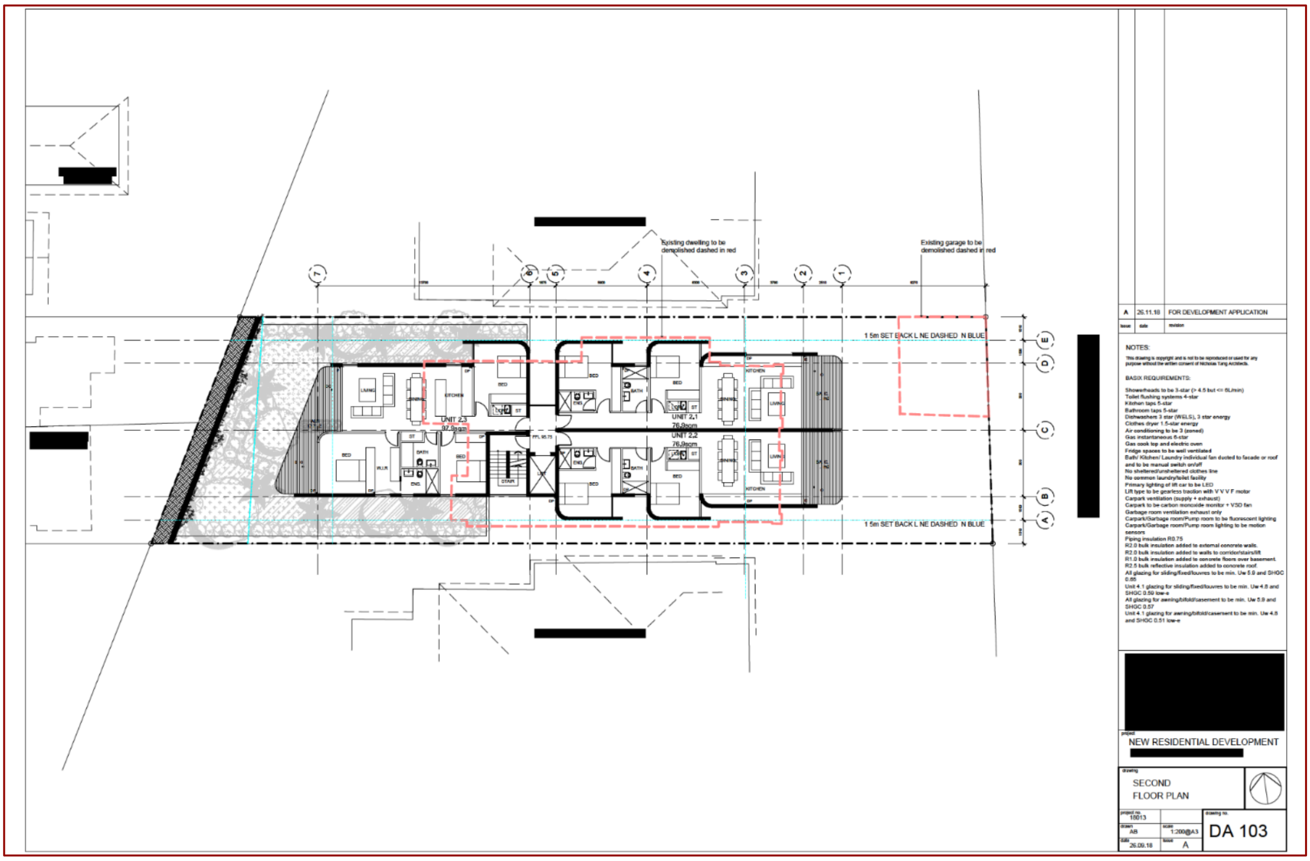


Figure B.32 BASIX Mid-rise sample building second floor plan

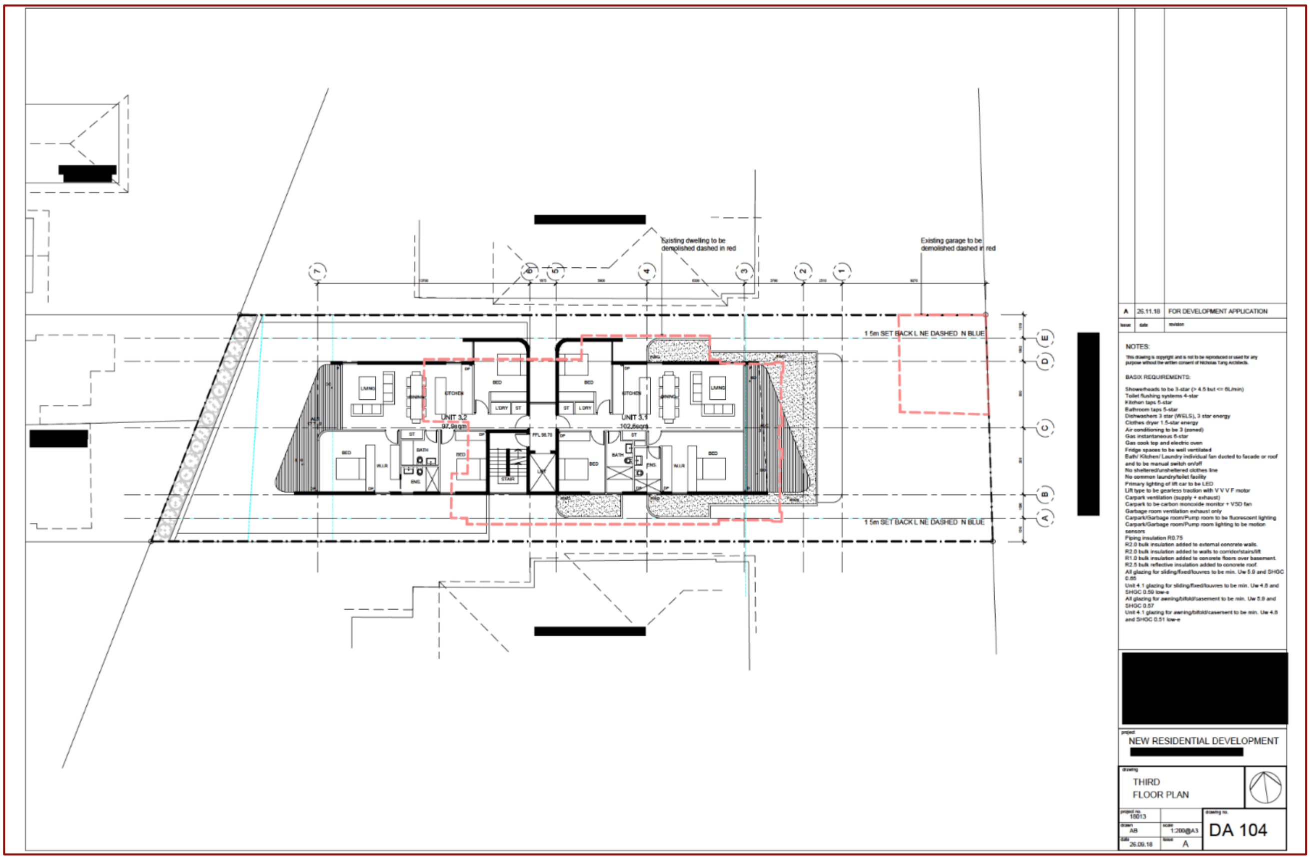


Figure B.33 BASIX Mid-rise sample building third floor plan

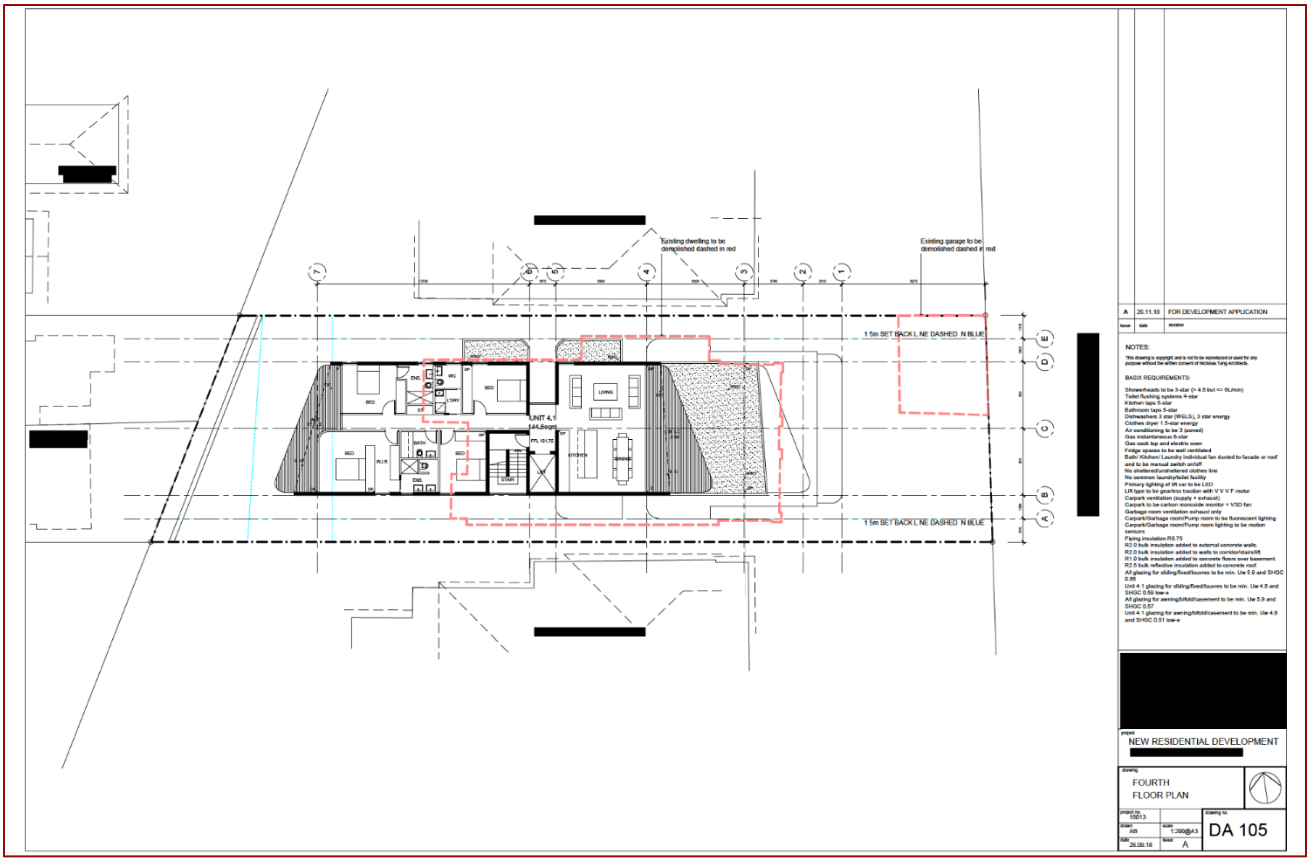


Figure B.34 BASIX Mid-rise sample building fourth floor plan

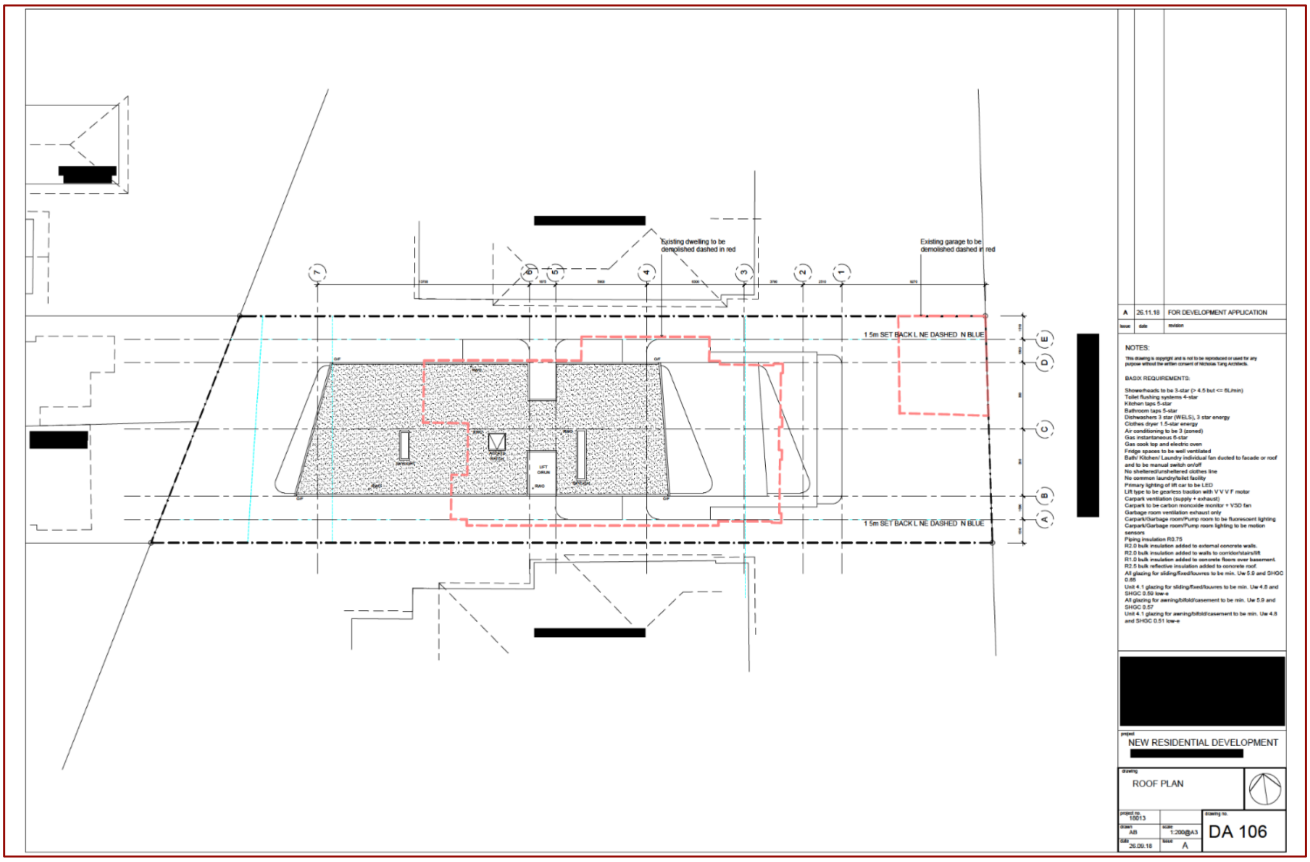


Figure B.35 BASIX Mid-rise sample building roof plan

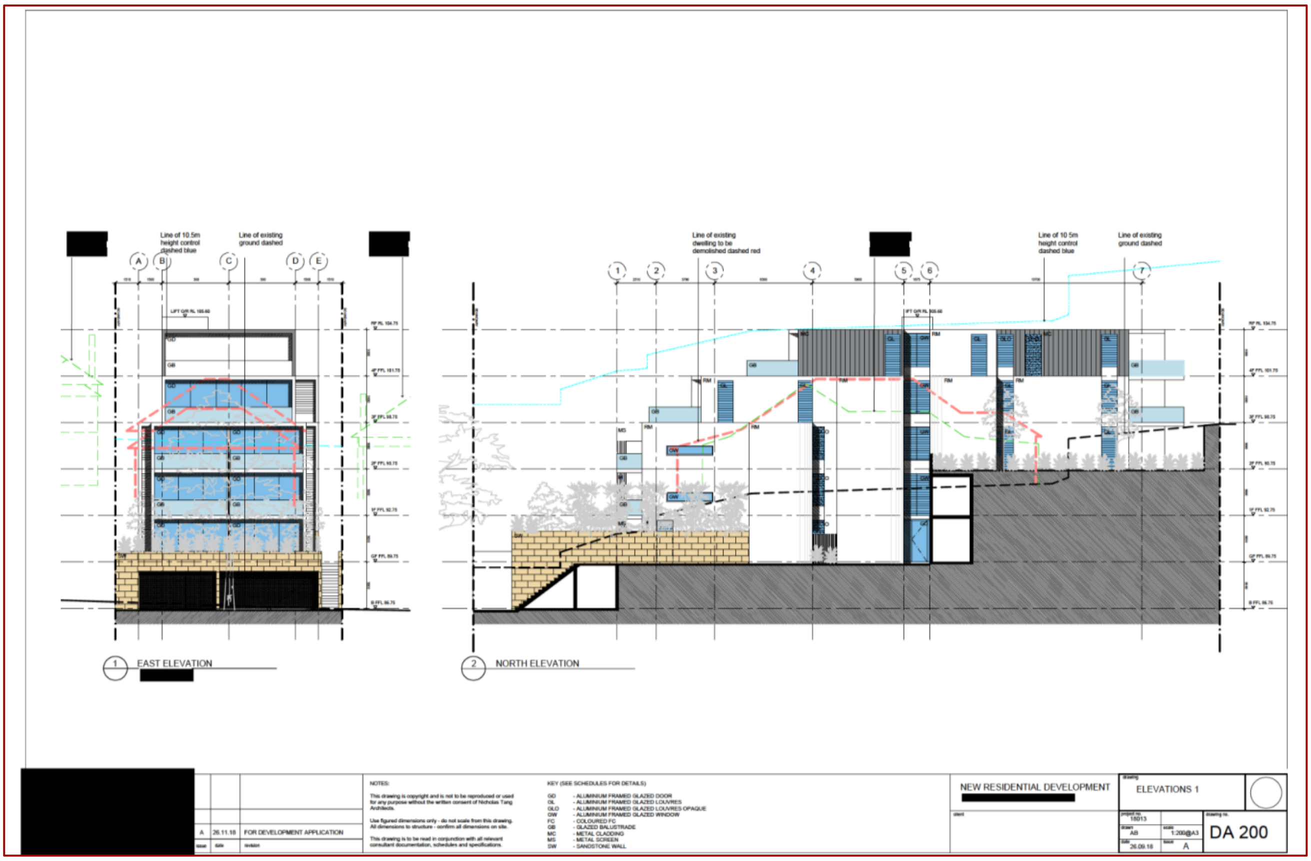


Figure B.36 BASIX Mid-rise sample building east and north elevations

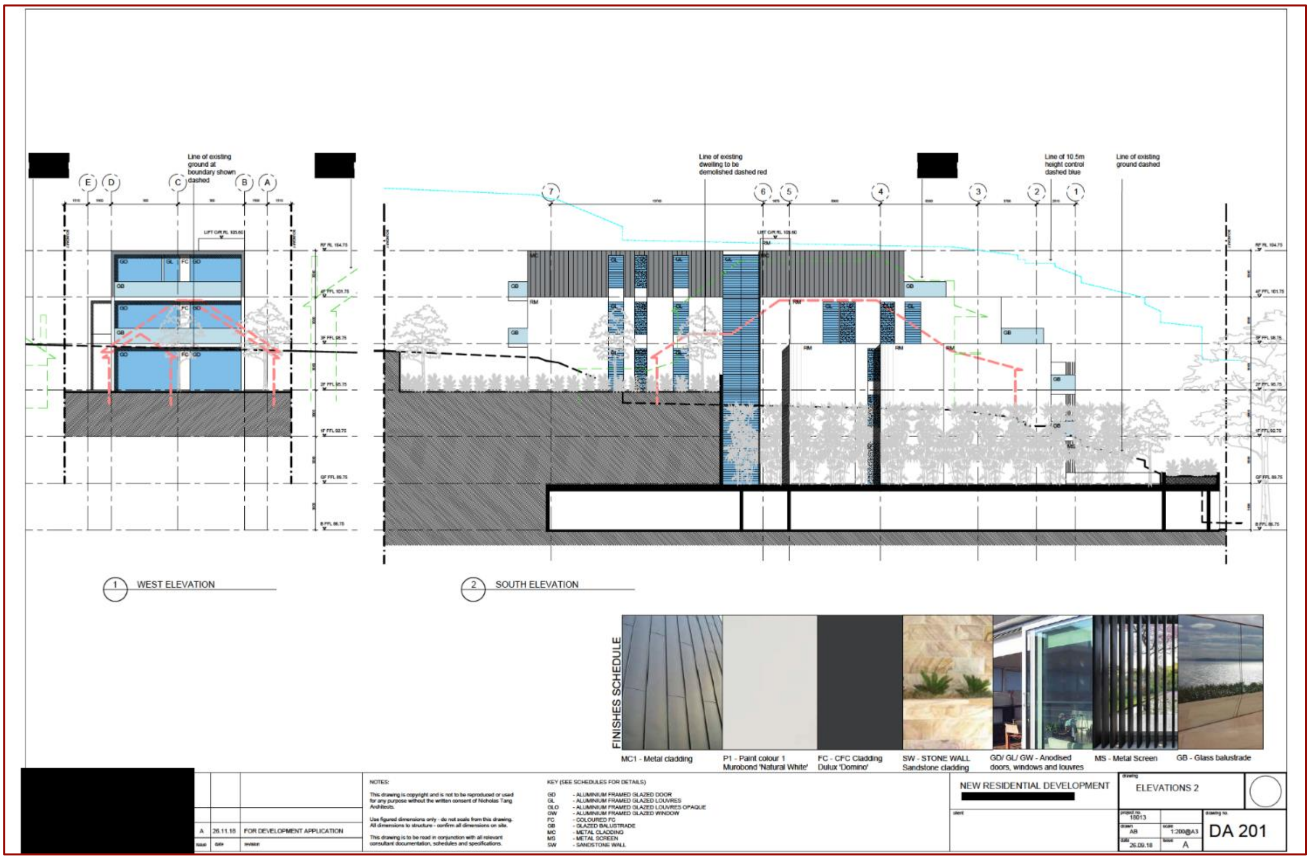


Figure B.37 BASIX Mid-rise sample building west and south elevations

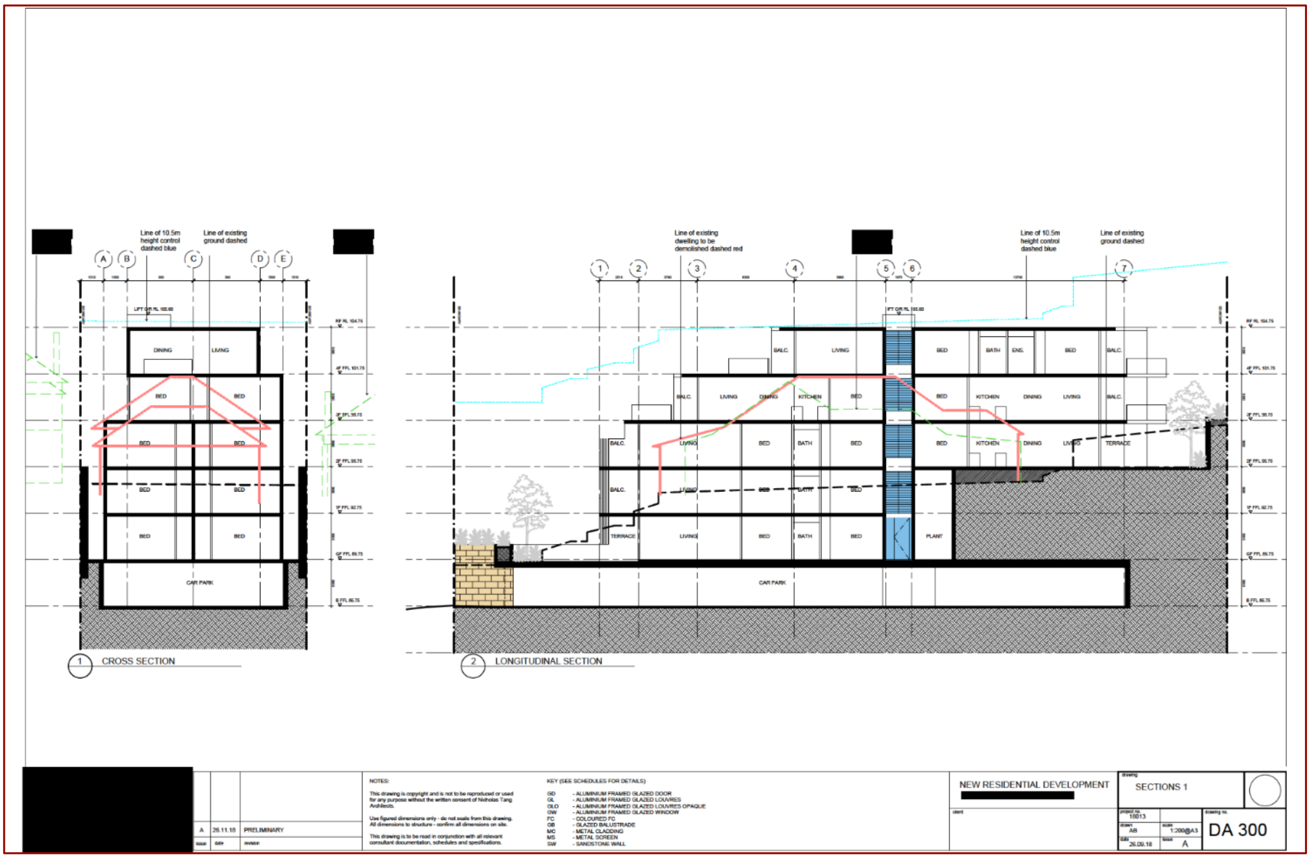


Figure B.38 BASIX Mid-rise sample building sections

B5 BASIX SAMPLE HIGH-RISE BUILDING

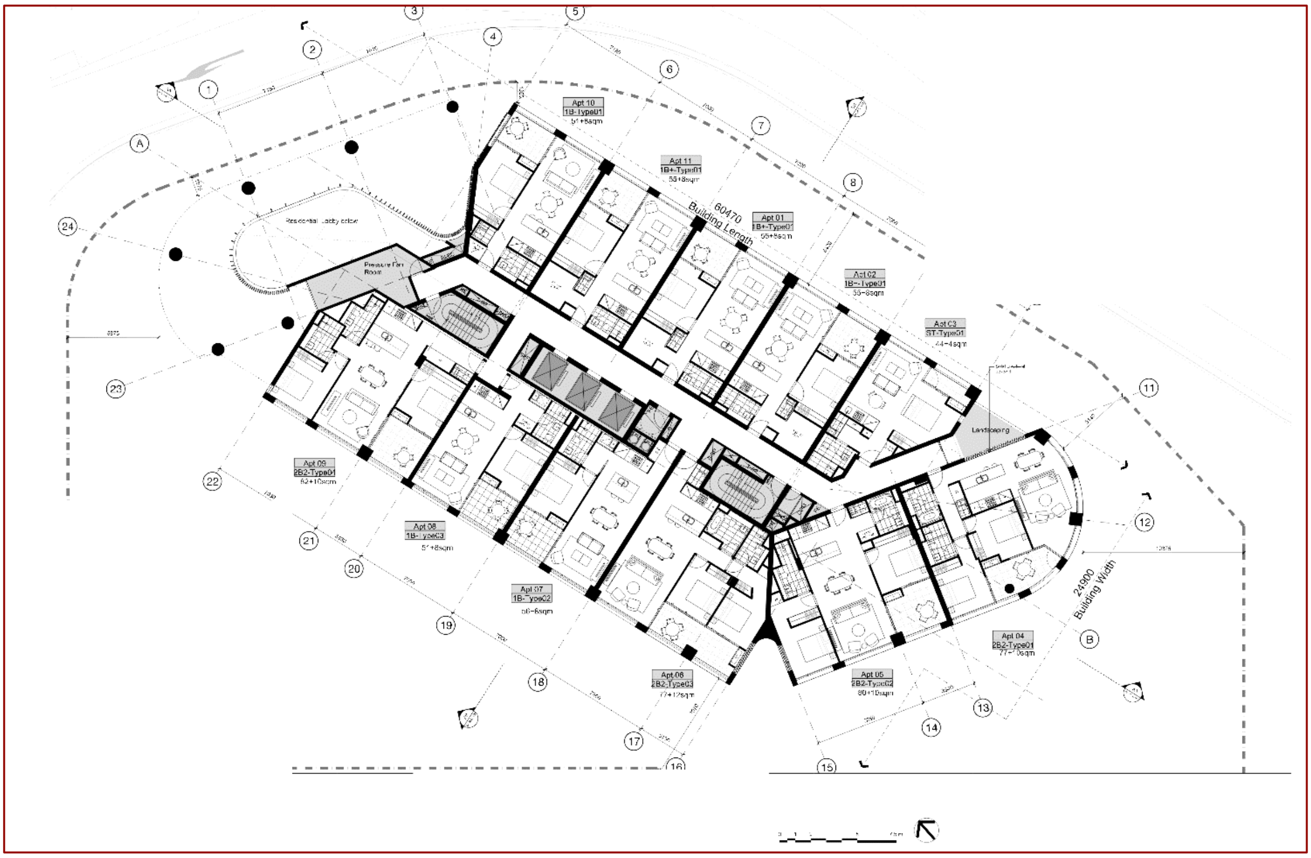


Figure B.39 BASIX High-rise sample building representative floor plan

Figure B.40 BASIX High-rise sample building representative north elevation

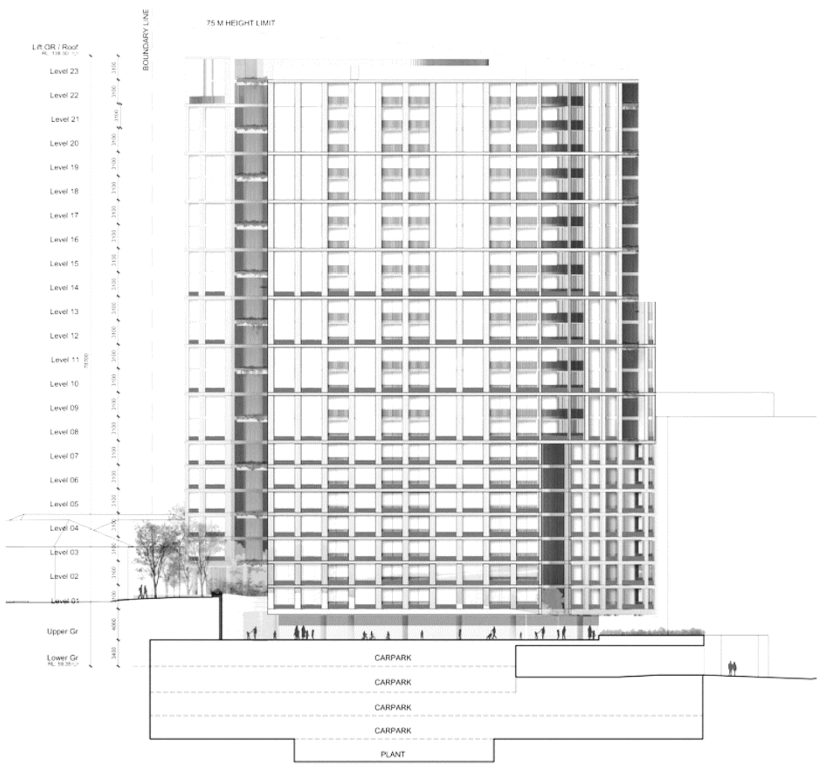


Figure B.41 BASIX High-rise sample building representative east elevation

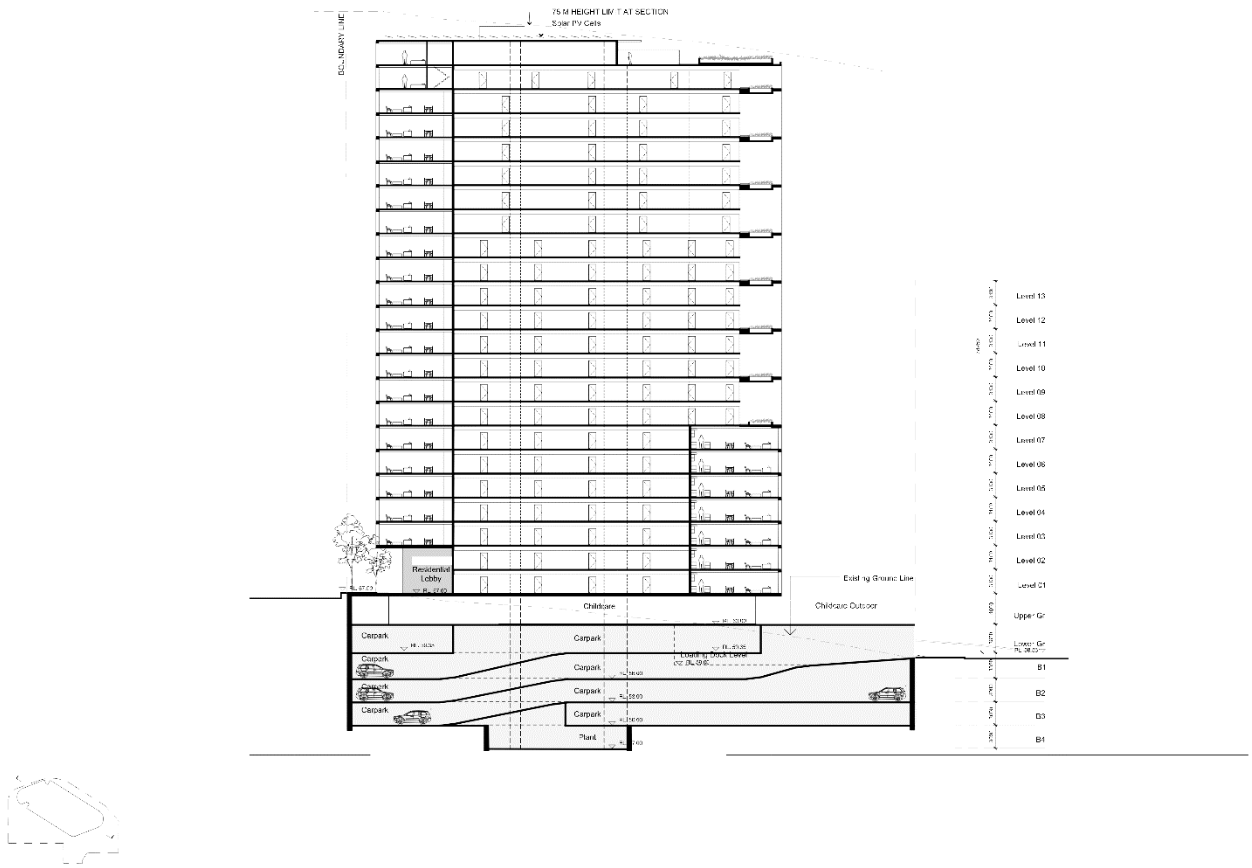


Figure B.42 BASIX High-rise sample building representative section

APPENDIX C

BASIX CERTIFICATE SUMMARY PAGES - BASELINE YEAR, 2030 & 2070

Note – as these certificates are copies of the official approved BASIX certificates, re-created for the purposes of testing in this study, they are not formally issued and therefore bear the 'This is not a valid certificate' watermark.

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Detached
Street address	n/a Street Dover Heights 2030
Local Government Area	Waverley Council
Plan type and plan number	deposited n/a
Lot no.	n/a
Section no.	-
Project type	separate dwelling house
No. of bedrooms	4

Project score		
Water	40	Target 40
Thermal Comfort	Pass	Target Pass
Energy	50	Target 50

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Attached
Street address	n/a Street Woollahra 2025
Local Government Area	Woollahra Municipal Council
Plan type and plan number	deposited n/a
Lot no.	n/a
Section no.	-
No. of residential flat buildings	0
No. of units in residential flat buildings	0
No. of multi-dwelling houses	2
No. of single dwelling houses	0

Project score		
Water	41	Target 40
Thermal Comfort	Pass	Target Pass
Energy	50	Target 50

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Low-rise
Street address	n/a Street Randwick 2031
Local Government Area	Randwick City Council
Plan type and plan number	deposited n/a
Lot no.	n/a
Section no.	-
No. of residential flat buildings	1
No. of units in residential flat buildings	9
No. of multi-dwelling houses	0
No. of single dwelling houses	0

Project score		
Water	40	Target 40
Thermal Comfort	Pass	Target Pass
Energy	45	Target 45

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Mid-rise
Street address	n/a Street Woollahra 2025
Local Government Area	Woollahra Municipal Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
No. of residential flat buildings	1
No. of units in residential flat buildings	10
No. of multi-dwelling houses	0
No. of single dwelling houses	0

Project score		
Water	41	Target 40
Thermal Comfort	Pass	Target Pass
Energy	37	Target 35

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC High-rise
Street address	n/a Street Randwick 2031
Local Government Area	Randwick City Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
No. of residential flat buildings	1
No. of units in residential flat buildings	195
No. of multi-dwelling houses	0
No. of single dwelling houses	0

Project score		
Water	40	Target 40
Thermal Comfort	Pass	Target Pass
Energy	25	Target 25

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Detached 2030TC
Street address	n/a Street Dover Heights 2030
Local Government Area	Waverley Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
Project type	separate dwelling house
No. of bedrooms	4

Project score		
Water	-21	Target 40
Thermal Comfort	Fail	Target Pass
Energy	50	Target 50

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Attached 2030TC
Street address	n/a Street Woollahra 2025
Local Government Area	Woollahra Municipal Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
No. of residential flat buildings	0
No. of units in residential flat buildings	0
No. of multi-dwelling houses	2
No. of single dwelling houses	0

Project score		
Water	-9	Target 40
Thermal Comfort	Fail	Target Pass
Energy	48	Target 50

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Low-rise 2030TC
Street address	n/a Street Randwick 2031
Local Government Area	Randwick City Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
No. of residential flat buildings	1
No. of units in residential flat buildings	9
No. of multi-dwelling houses	0
No. of single dwelling houses	0

Project score		
Water	24	Target 40
Thermal Comfort	Fail	Target Pass
Energy	45	Target 45

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Mid-rise 2030TC
Street address	n/a Street Woollahra 2025
Local Government Area	Woollahra Municipal Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
No. of residential flat buildings	1
No. of units in residential flat buildings	10
No. of multi-dwelling houses	0
No. of single dwelling houses	0

Project score		
Water	18	Target 40
Thermal Comfort	Fail	Target Pass
Energy	36	Target 35

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC High-rise 2030TC
Street address	n/a Street Randwick 2031
Local Government Area	Randwick City Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
No. of residential flat buildings	1
No. of units in residential flat buildings	195
No. of multi-dwelling houses	0
No. of single dwelling houses	0

Project score		
Water	39	Target 40
Thermal Comfort	Fail	Target Pass
Energy	30	Target 25

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Detached 2070TC
Street address	n/a Street Dover Heights 2030
Local Government Area	Waverley Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
Project type	separate dwelling house
No. of bedrooms	4

Project score		
Water	6	Target 40
Thermal Comfort	Fail	Target Pass
Energy	45	Target 50

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Attached 2070TC
Street address	n/a Street Woollahra 2025
Local Government Area	Woollahra Municipal Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
No. of residential flat buildings	0
No. of units in residential flat buildings	0
No. of multi-dwelling houses	2
No. of single dwelling houses	0

Project score		
Water	16	Target 40
Thermal Comfort	Fail	Target Pass
Energy	41	Target 50

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Low-rise 2070TC
Street address	n/a Street Randwick 2031
Local Government Area	Randwick City Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
No. of residential flat buildings	1
No. of units in residential flat buildings	9
No. of multi-dwelling houses	0
No. of single dwelling houses	0

Project score		
Water	29	Target 40
Thermal Comfort	Fail	Target Pass
Energy	40	Target 45

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC Mid-rise 2070TC
Street address	n/a Street Woollahra 2025
Local Government Area	Woollahra Municipal Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
No. of residential flat buildings	1
No. of units in residential flat buildings	10
No. of multi-dwelling houses	0
No. of single dwelling houses	0

Project score		
Water	24	Target 40
Thermal Comfort	Fail	Target Pass
Energy	32	Target 35

BASIX® Report

Building Sustainability Index www.basix.nsw.gov.au

Project summary	
Project name	FPRCC High-rise 2070TC
Street address	n/a Street Randwick 2031
Local Government Area	Randwick City Council
Plan type and plan number	deposited -
Lot no.	-
Section no.	-
No. of residential flat buildings	1
No. of units in residential flat buildings	195
No. of multi-dwelling houses	0
No. of single dwelling houses	0

Project score		
Water	40	Target 40
Thermal Comfort	Fail	Target Pass
Energy	27	Target 25

APPENDIX D

NatHERS THERMAL COMFORT MODELLING DETAILED RESULTS

D1 INDIVIDUAL NATHERS TARGETS & SCORES

The following tables present the individual dwelling results for heating and cooling loads in each BASIX sample building modelled.

Green values represent loads within the baseline year BASIX targets.

Red values are for loads that exceed the targets and would presently be deemed non-compliant for BASIX.

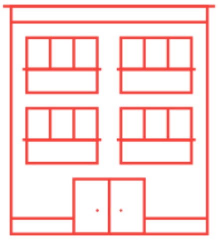
D1.1 DETACHED (SINGLE) DWELLING

	BASELINE YEAR				2030		2070	
	BASIX targets		NatHERS Results		NatHERS Results		NatHERS Results	
Building Type	Heating (MJ/m²)	Cooling (MJ/m²)	Heating (MJ/m²)	Cooling (MJ/m²)	Heating (MJ/m²)	Cooling (MJ/m²)	Heating (MJ/m²)	Cooling (MJ/m²)
Detached  1 dwelling	**40**	**26**	**30.9**	**20.8**	**8.8**	**37.3**	**2.1**	**91.6**

D1.2 ATTACHED DWELLINGS (SEMIS, DUPLEXES)

		BASELINE YEAR				2030		2070	
		BASIX targets		NatHERS Results		NatHERS Results		NatHERS Results	
Building Type	**UNIT**	Heating (MJ/m²)	Cooling (MJ/m²)	Heating (MJ/m²)	Cooling (MJ/m²)	Heating (MJ/m²)	Cooling (MJ/m²)	Heating (MJ/m²)	Cooling (MJ/m²)
Attached  2 dwellings in total	**A**	**40**	**26**	**15.7**	**21.9**	**4.9**	**40.1**	**1.4**	**103.4**
	B			**28.6**	**25.7**	**9.3**	**41.6**	**2.3**	**101.5**

D1.3 LOW-RISE MULTI UNIT DEVELOPMENT

		BASELINE YEAR				2030		2070	
		BASIX targets		NatHERS Results		NatHERS Results		NatHERS Results	
Building Type	**UNIT**	**Heating (MJ/m^2)**	**Cooling (MJ/m^2)**	**Heating (MJ/m^2)**	**Cooling (MJ/m^2)**	**Heating (MJ/m^2)**	**Cooling (MJ/m^2)**	**Heating (MJ/m^2)**	**Cooling (MJ/m^2)**
Low-rise  9 dwellings in total	1			44.2	23.3	18.7	37.2	5.8	88.1
	2			43.1	28.8	14.8	47.5	5.7	85.4
	3			18.6	26.4	6.1	41.2	2.0	100.6
	4			28.9	20.5	12.2	31.0	4.1	74.9
	5	45.4	29.5	32.2	26.1	12.9	40.3	4.2	92.2
	6			13.4	25.3	5.0	42.6	1.9	96.7
	7			37.0	25.3	17.1	35.1	7.0	81.7
	8			45.1	28.9	16.0	43.3	5.3	106.2
	9			22.8	27.3	13.2	41.8	5.5	94.9

D1.4 MID-RISE MULTI UNIT DEVELOPMENT

		BASELINE YEAR				2030		2070	
		BASIX targets		NatHERS Results		NatHERS Results		NatHERS Results	
Building Type	**UNIT**	**Heating (MJ/m^2)**	**Cooling (MJ/m^2)**	**Heating (MJ/m^2)**	**Cooling (MJ/m^2)**	**Heating (MJ/m^2)**	**Cooling (MJ/m^2)**	**Heating (MJ/m^2)**	**Cooling (MJ/m^2)**
Mid-rise  10 dwellings in total	0.1			24.9	20.4	8.2	30.3	2.4	79.4
	0.2			45.1	17.4	17.3	28.7	5.1	74.9
	1.1			15.0	21.1	4.7	30.5	1.3	77.3
	1.2			33.8	18.6	14.3	30.7	5.1	77.0
	2.1			16.3	21.1	5.0	33.9	1.4	82.5
	2.2	45.4	29.5	40.8	18.5	18.4	30.1	7.2	75.1
	2.3			28.9	24.4	9.2	49.0	2.2	112.0
	3.1			34.0	24.1	14.6	35.8	5.9	79.8
	3.2			30.3	24.0	14.3	45.5	5.4	106.1
	4.1			40.4	21.9	18.7	34.8	7.4	79.6

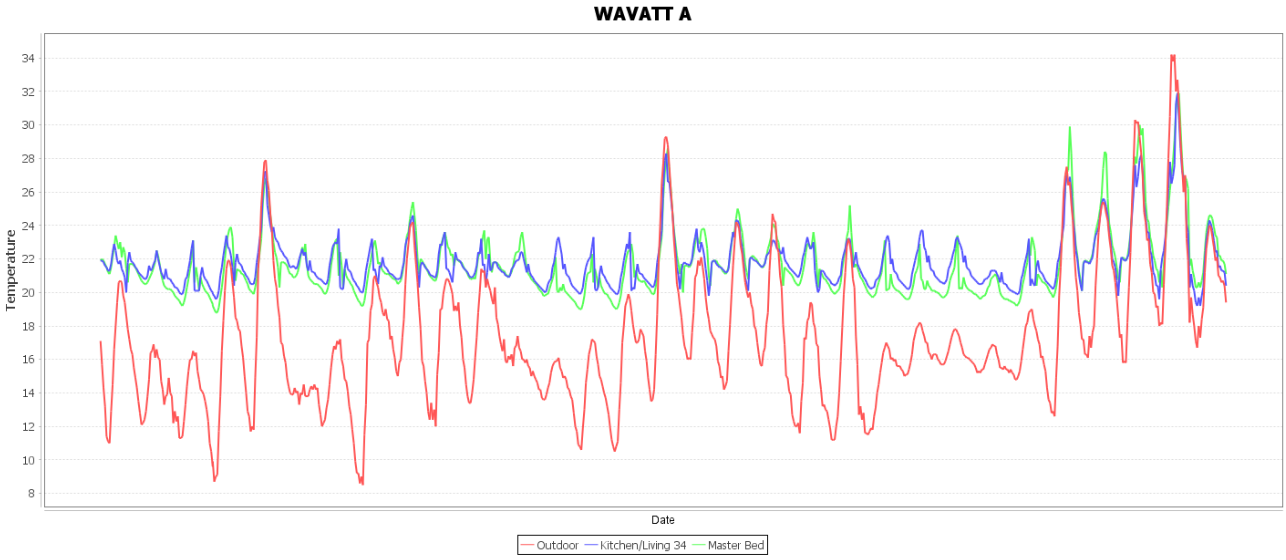
D1.5 HIGH-RISE MULTI UNIT DEVELOPMENT

Building Type	UNIT	BASELINE YEAR				2030		2070	
		BASIX targets		NatHERS Results		NatHERS Results		NatHERS Results	
		Heating (MJ/m²)	Cooling (MJ/m²)	Heating (MJ/m²)	Cooling (MJ/m²)	Heating (MJ/m²)	Cooling (MJ/m²)	Heating (MJ/m²)	Cooling (MJ/m²)
High-rise  195 dwellings in total	1.01	45.4	29.5	13.0	19.3	4.7	29.7	1.9	76.8
	1.02			17.6	19.4	5.9	26.9	7.9	64.7
	1.03			20.0	16.8	6.8	25.4	2.2	61.1
	1.04			42.7	20.9	19.1	31.9	7.1	74.8
	1.05			28.1	21.8	12.5	36.4	3.7	82.6
	1.06			22.9	17.6	9.8	26.6	3.0	65.4
	1.07			12.8	20.7	5.3	37.2	1.7	89.2
	1.08			26.0	17.0	11.4	26.1	3.2	66.7
	1.09			22.5	28.7	9.4	41.8	3.0	91.8
	1.10			20.1	26.2	8.7	50.8	3.1	114.2
	1.11			5.8	16.7	2.2	27.6	0.7	75.5
	1.12			7.4	20.5	1.9	31.6	1.1	85.2
	1.13			15.1	19.4	4.7	35.7	3.4	75.9
	3.01 x 4			14.9	17.6	5.8	27.0	3.6	62.9
	3.02 x 4			19.8	18.3	7.5	26.0	4.2	56.2
	3.03 x 4			22.1	15.6	8.4	24.2	5.3	53.7
	3.04 x 4			33.9	26.7	14.3	39.8	9.2	68.4
	3.05 x 4			30.6	20.5	15.3	32.7	9.2	58.8
	3.06 x 4			25.5	15.8	12.5	25.0	7.2	57.5
	3.07 x 4			15.0	18.4	7.2	34.9	4.5	77.1
	3.08 x 4			28.5	14.9	14.2	24.4	7.6	58.1
	3.09 x 4			25.1	25.1	12.0	37.7	7.1	63.6
	3.10 x 4			23.2	23.9	11.2	47.7	7.5	89.1
	3.11 x 4			7.3	15.1	3.0	25.7	1.8	58.8
	3.12 x 4			9.5	18.8	3.1	29.8	1.9	58.8
	3.13 x 4			17.5	17.6	6.4	34.6	3.4	75.9
	10.01 x 5			20.7	13.4	9.6	24.6	3.6	62.9
	10.02 x 5			25.3	15.7	12.1	24.0	4.2	56.2
	10.03 x 5			29.4	12.1	14.7	21.6	5.3	53.7
	10.04 x 5			45.1	18.2	23.8	30.9	9.2	68.4
	10.05 x 5			39.9	11.5	25.0	24.5	9.2	58.8
	10.06 x 5			33.9	12.1	19.8	21.2	7.2	57.5
	10.07 x 5			21.9	14.2	13.0	28.2	4.5	77.1
	10.08 x 5			35.3	12.5	21.5	20.9	7.6	58.1
	10.09 x 5			32.3	14.9	19.0	25.0	7.1	63.6
	10.10 x 5			31.4	18.8	18.5	38.3	7.5	89.1
	10.11 x 5			11.8	12.0	6.2	21.6	1.8	58.8
	10.12 x 5			15.4	14.6	7.1	22.6	1.9	58.8
	10.13 x 5			24.5	15.6	12.2	30.1	3.4	75.9
	12.01 x 5			22.6	12.3	11.0	25.3	4.0	62.2
	12.02 x 5			27.3	15.4	13.8	23.5	4.9	56.0
	12.03 x 5			29.8	11.7	15.1	21.5	5.4	53.7
	12.04 x 5			45.1	18.2	23.8	30.9	9.2	68.4
	12.05 x 5			39.9	11.5	25.0	24.5	9.2	58.8
	12.06 x 5			34.8	10.4	22.4	21.1	8.4	56.5
	12.07 x 5			23.5	10.8	15.2	26.8	5.4	74.3
	12.08 x 5			37.7	11.6	24.0	19.8	8.7	58.6
	12.09 x 5			34.9	12.4	21.6	20.9	8.2	57.3
	12.10 x 5			35.2	16.3	21.0	35.6	8.8	85.3
	12.11 x 5			14.7	10.4	7.6	20.5	2.2	56.0
	12.12 x 5			18.0	12.9	8.9	22.3	2.5	57.8
	12.13 x 5			26.9	14.4	14.3	28.6	4.3	75.0

APPENDIX E

CURRENT AND FUTURE CLIMATE TRENDS AND INTERNAL CONDITIONS

E1 OCTOBER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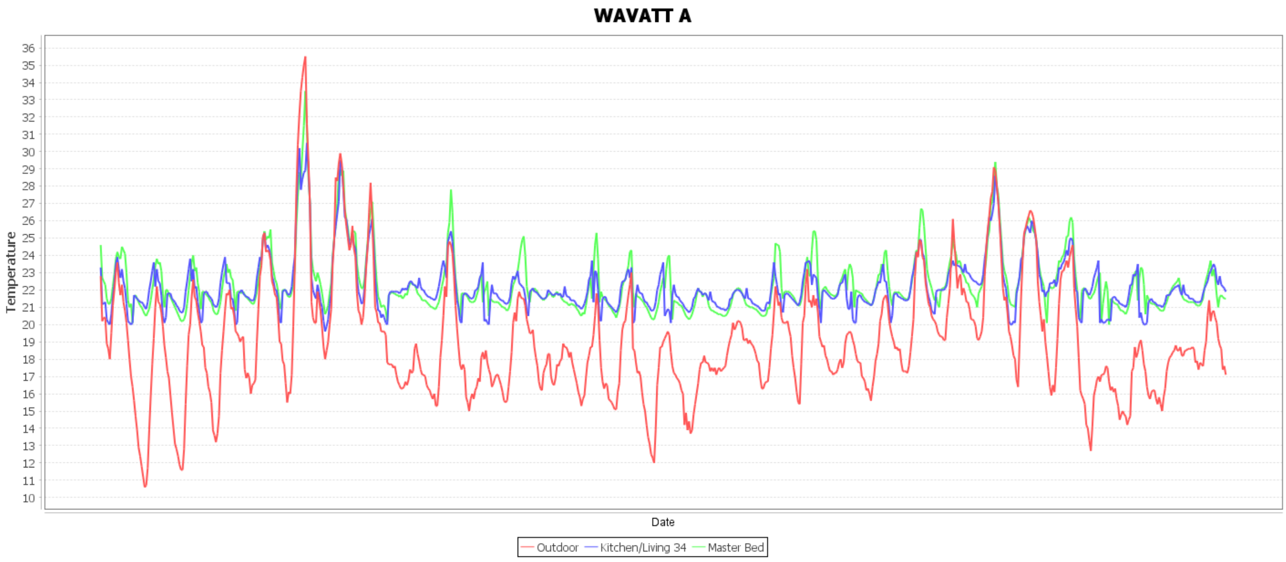
Outdoor
Kitchen/Living 34
Master Bed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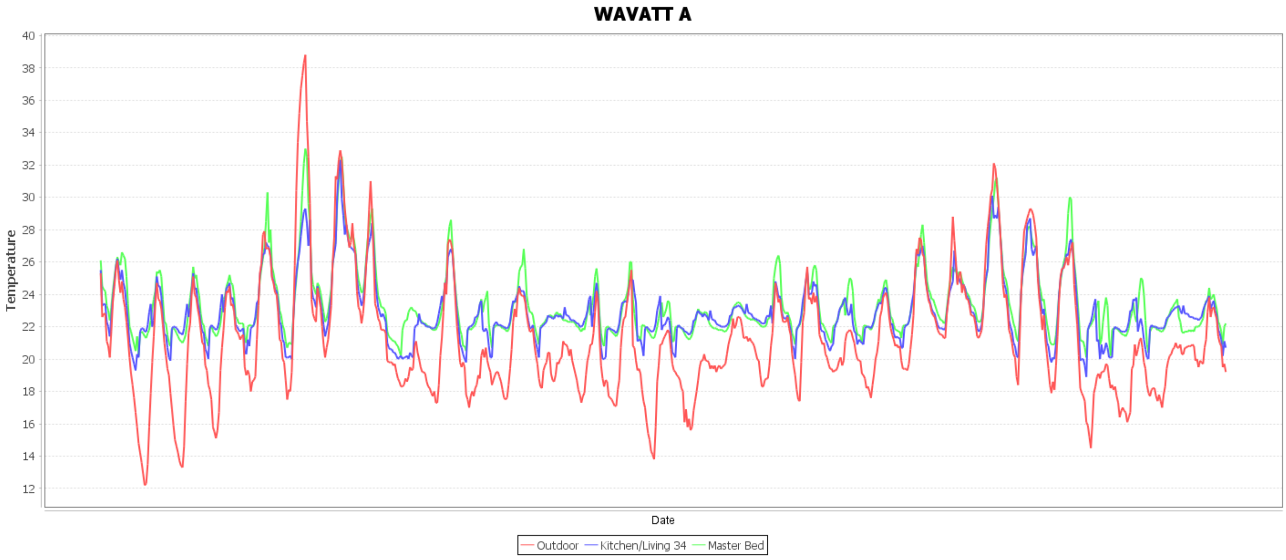
Outdoor
Kitchen/Living 34
Master Bed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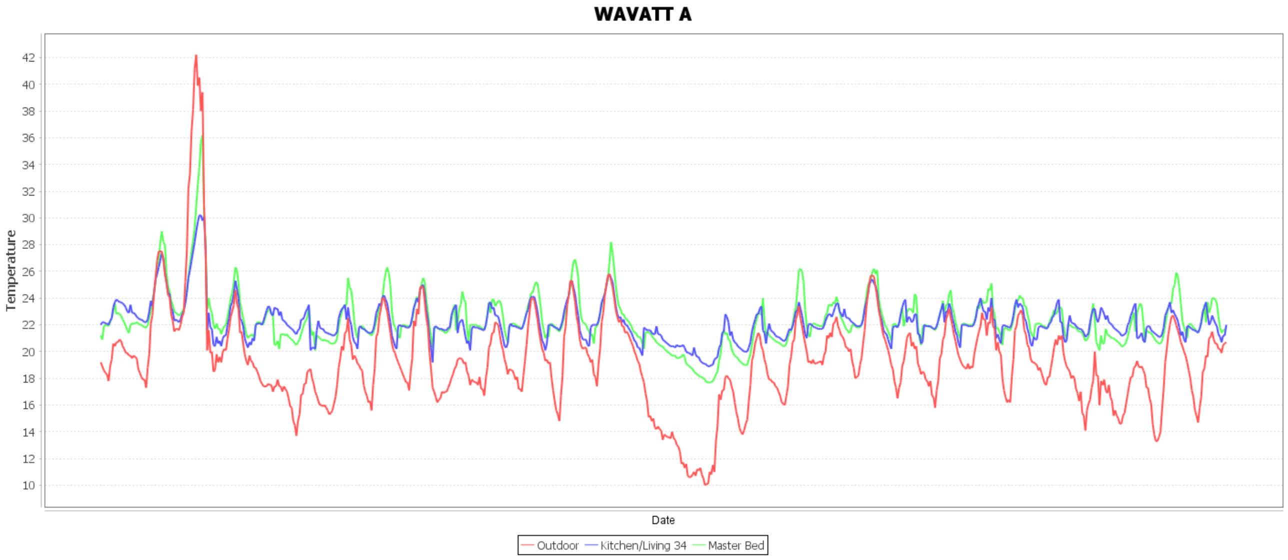
Temperature
Date
Outdoor
Kitchen/Living 34
Master Bed

E2 NOVEMBER



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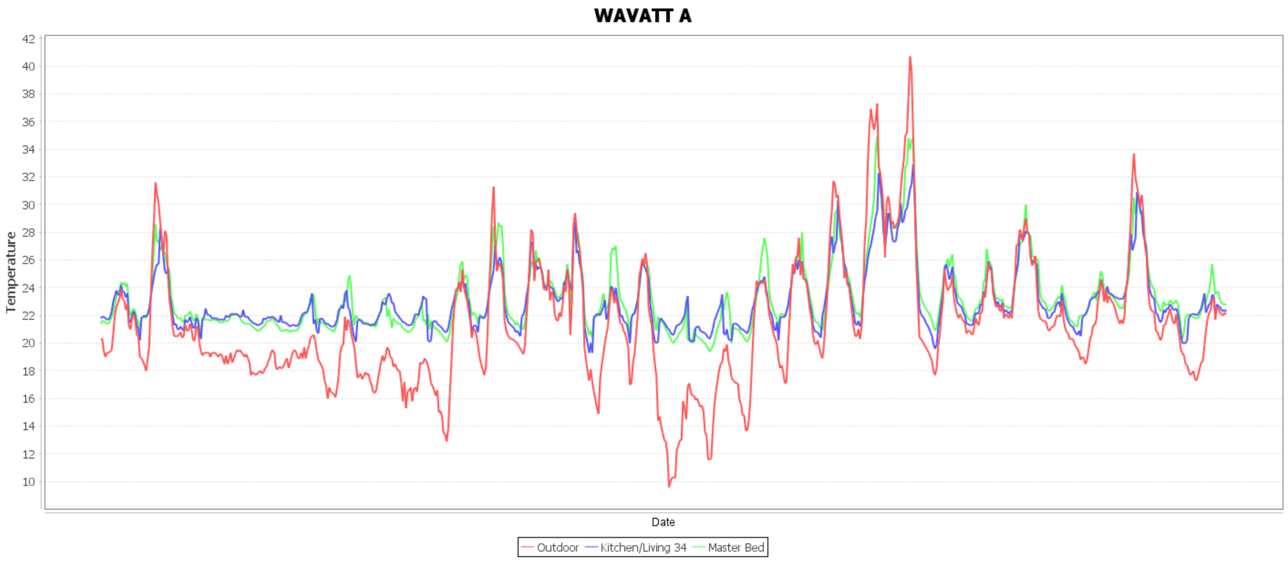
12
10
Date
Outdoor
Kitchen/Living 34
Master Bed



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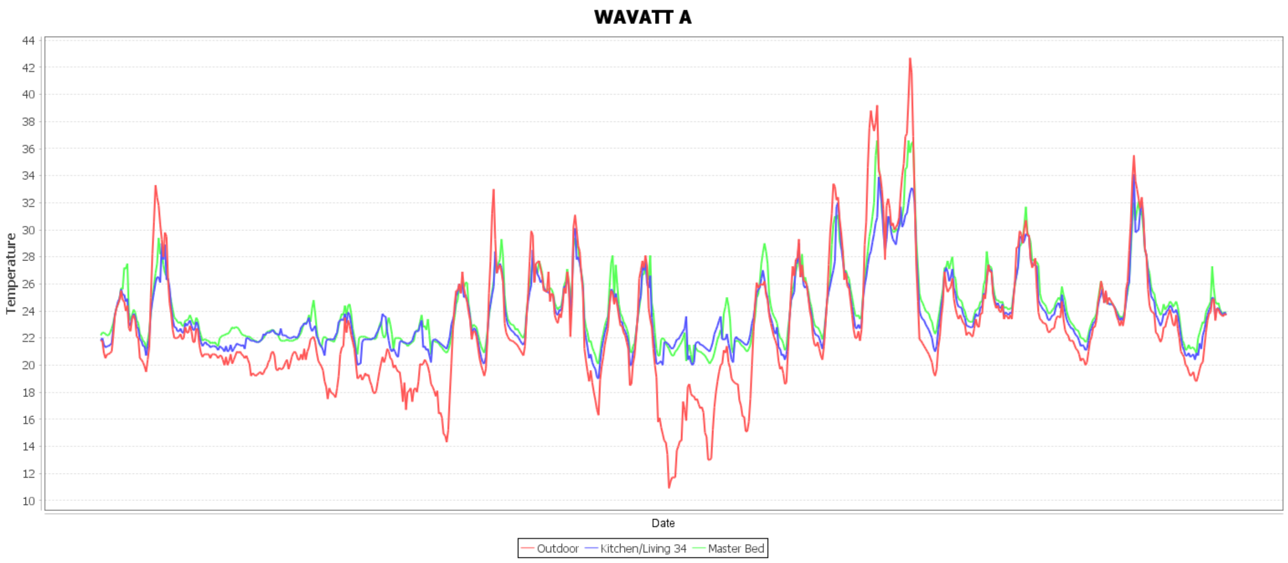
Date
Outdoor
Kitchen/Living 34
Master Bed



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Date
Outdoor
Kitchen/Living 34
Master Bed

E3 DECEMBER

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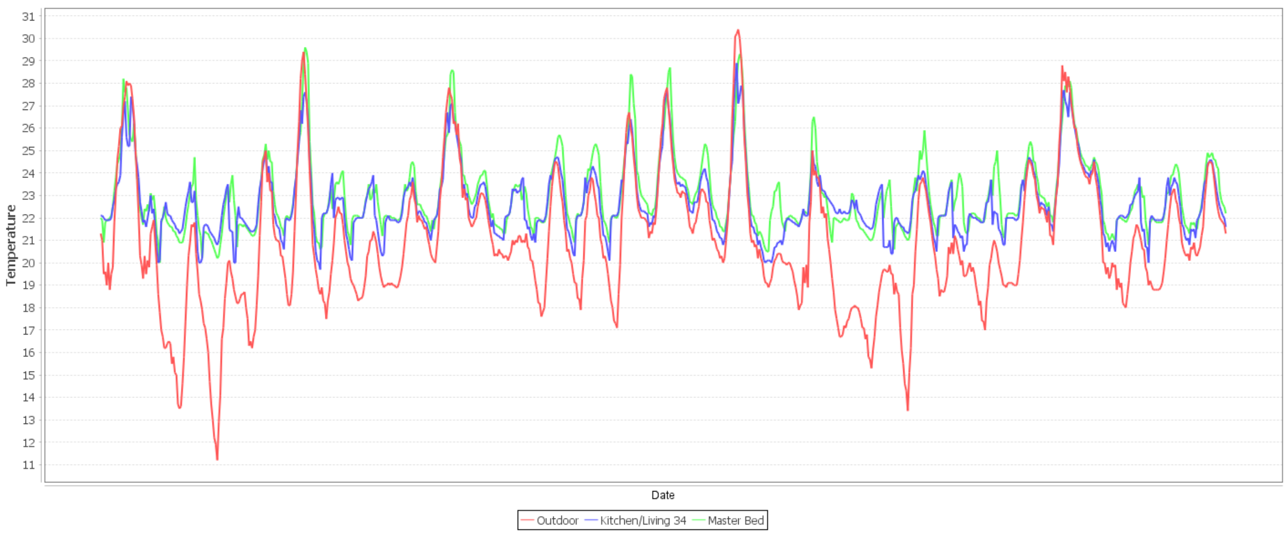

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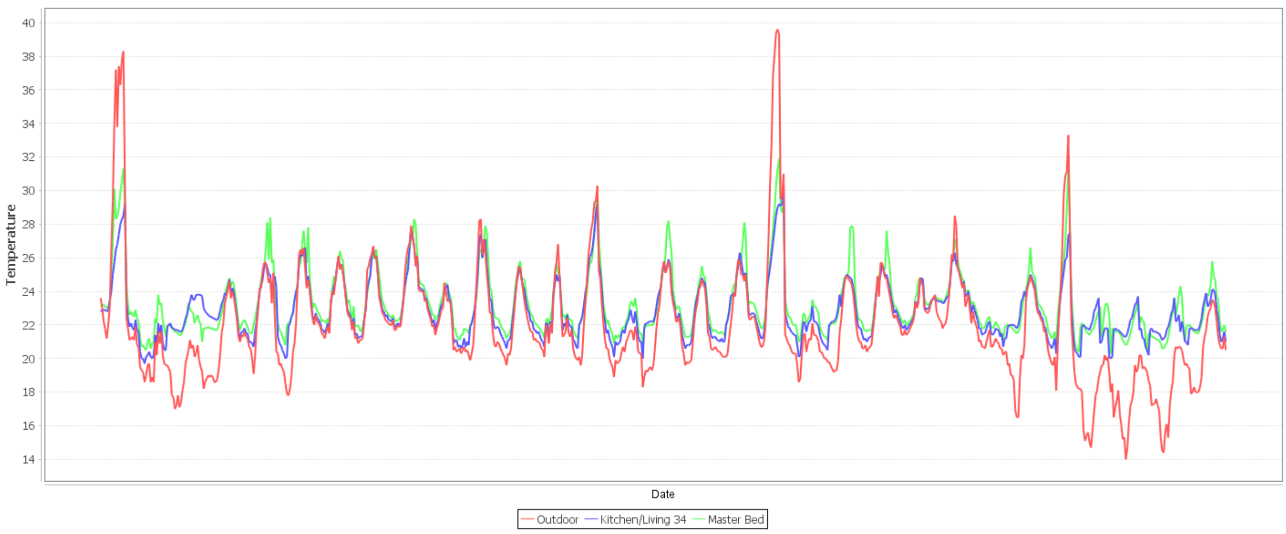

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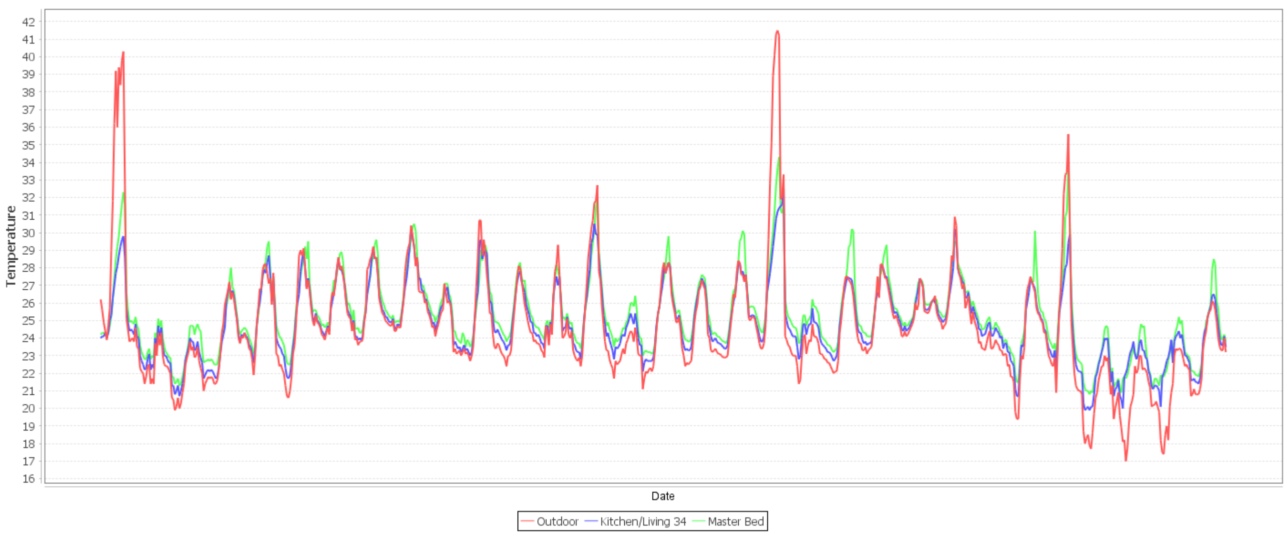

E4 JANUARY

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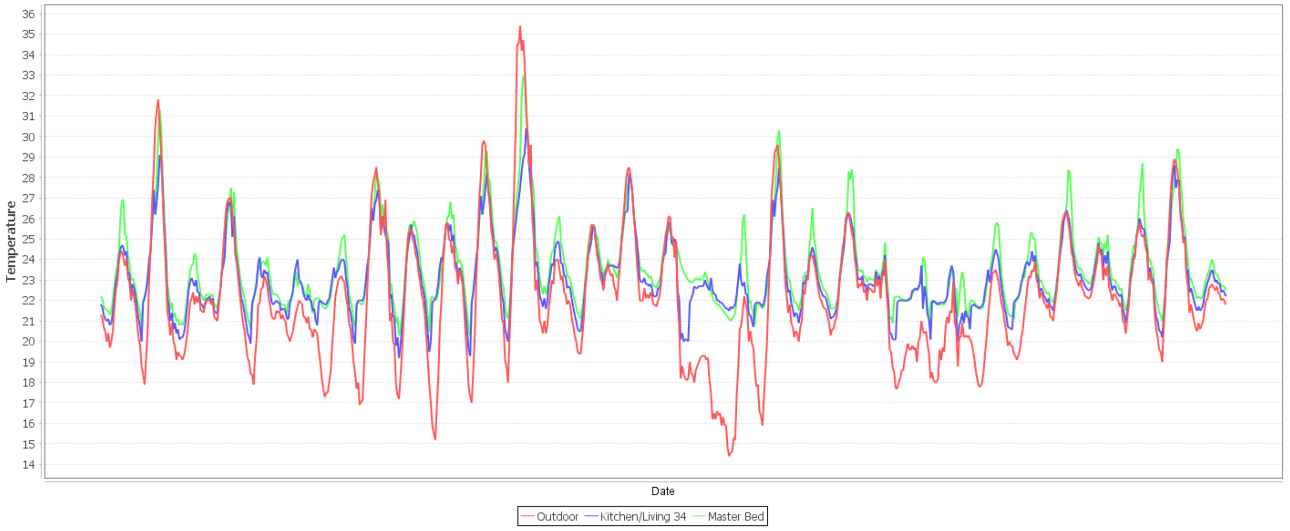

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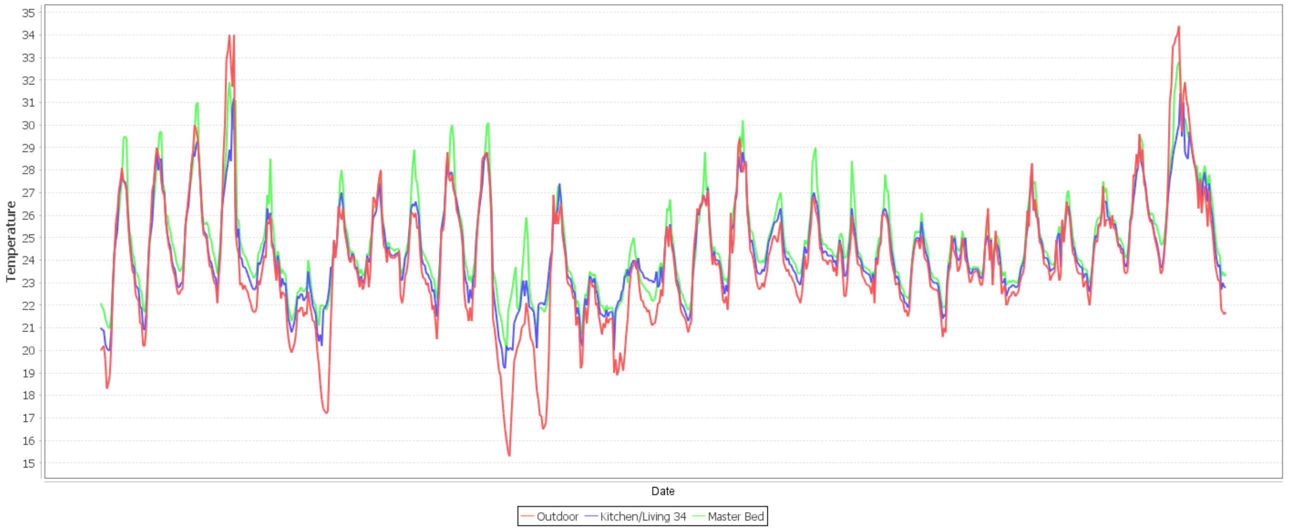

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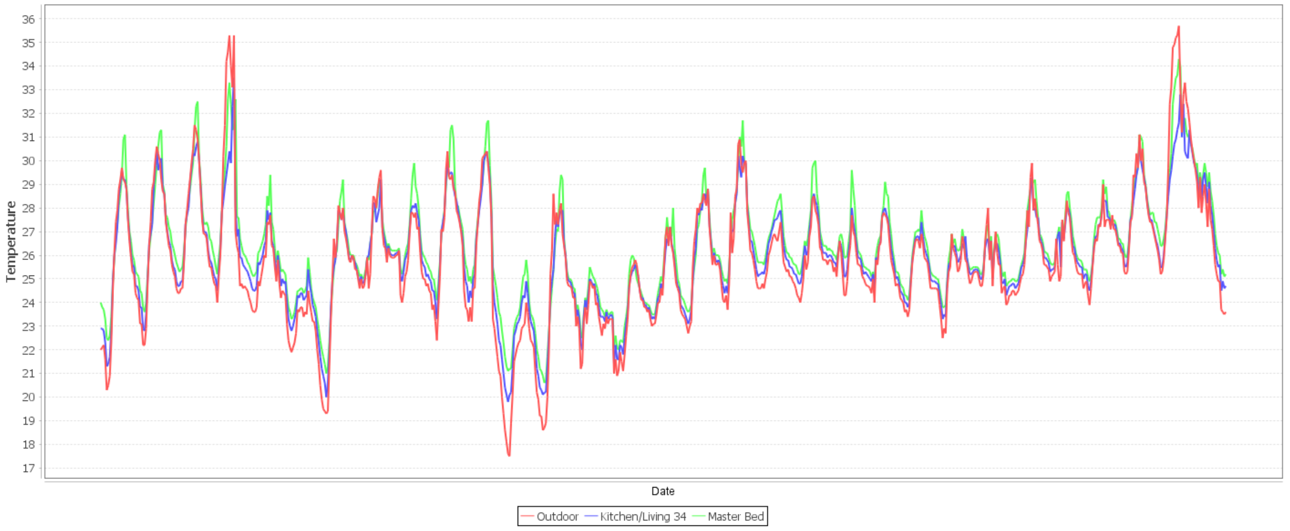

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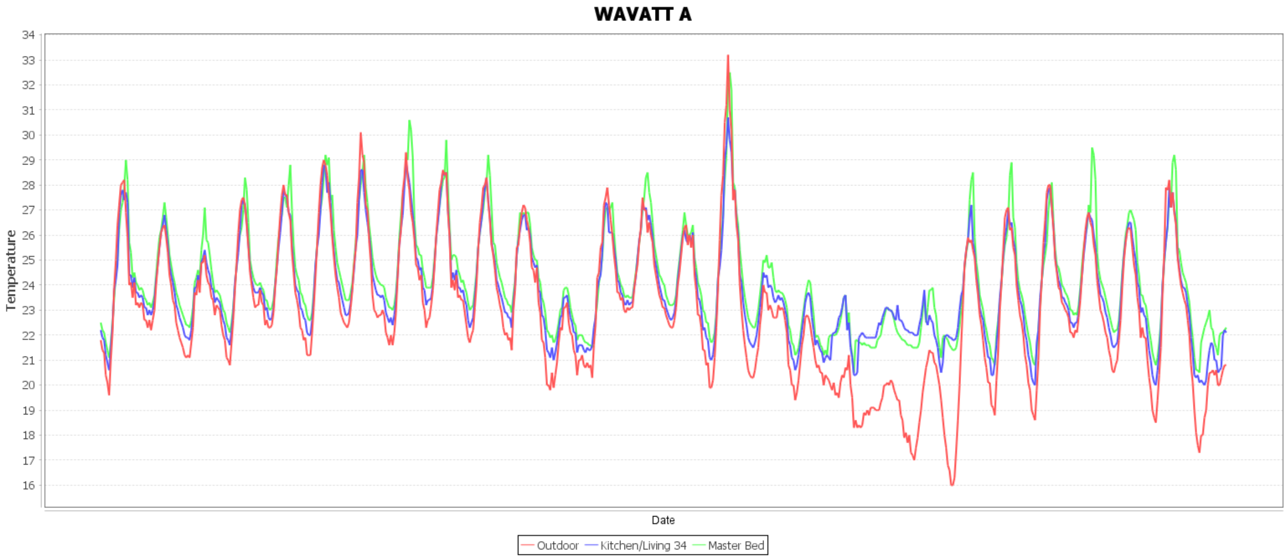
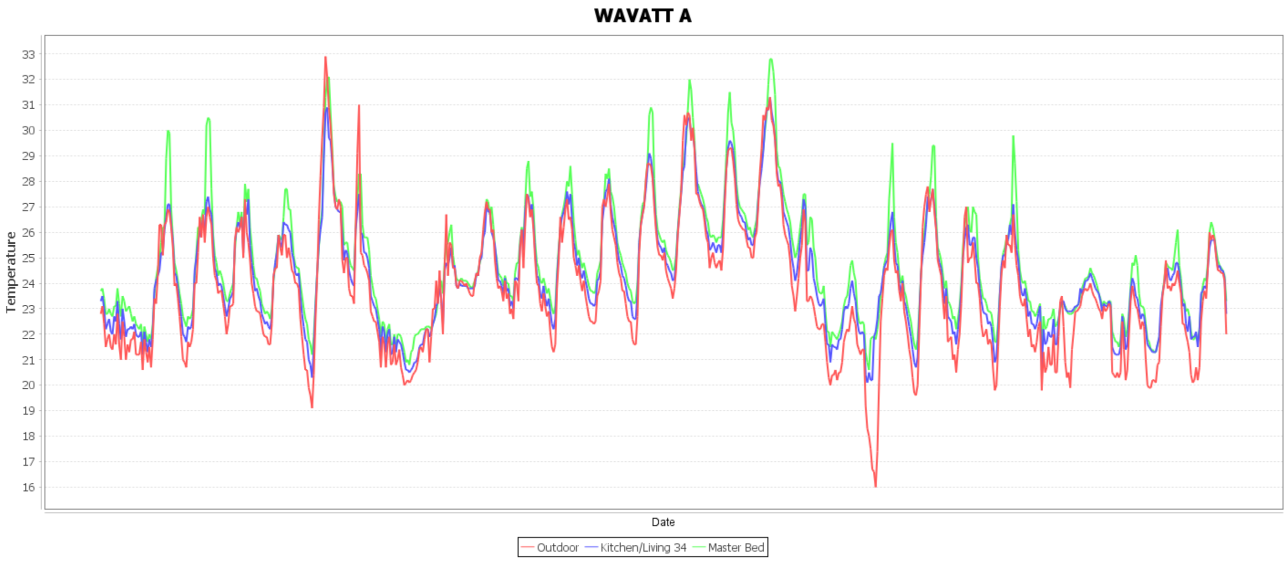

WAVATT A
Temperature
Date
Outdoor
Kitchen/Living 34
Master Bed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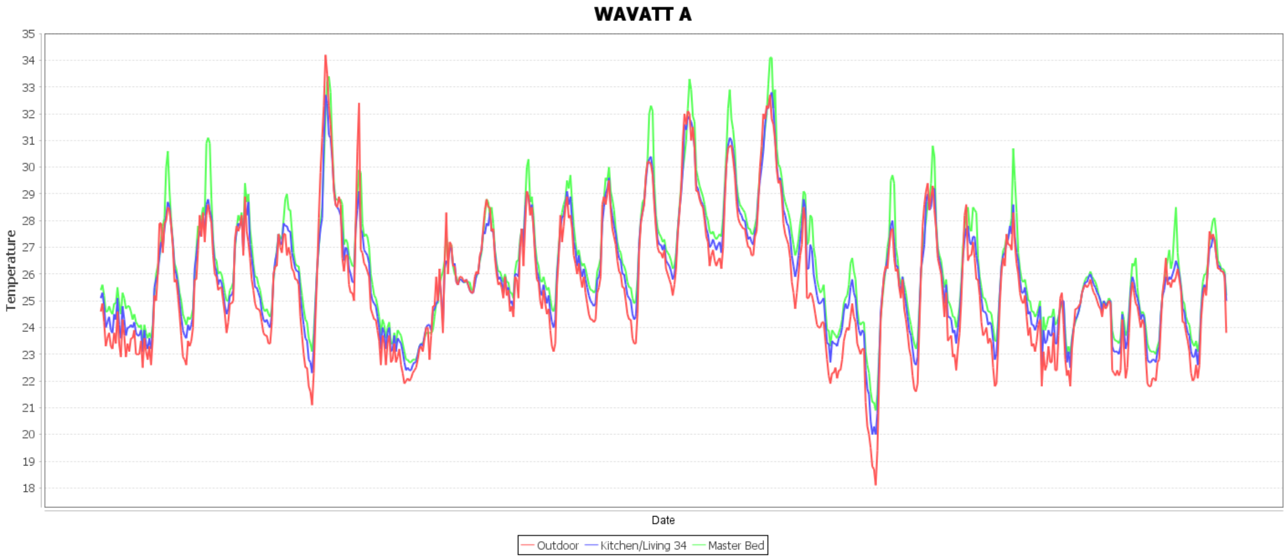
Temperature
Date
Outdoor
Kitchen/Living 34
Master Bed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Date
Outdoor
Kitchen/Living 34
Master Bed

E6 MARCH

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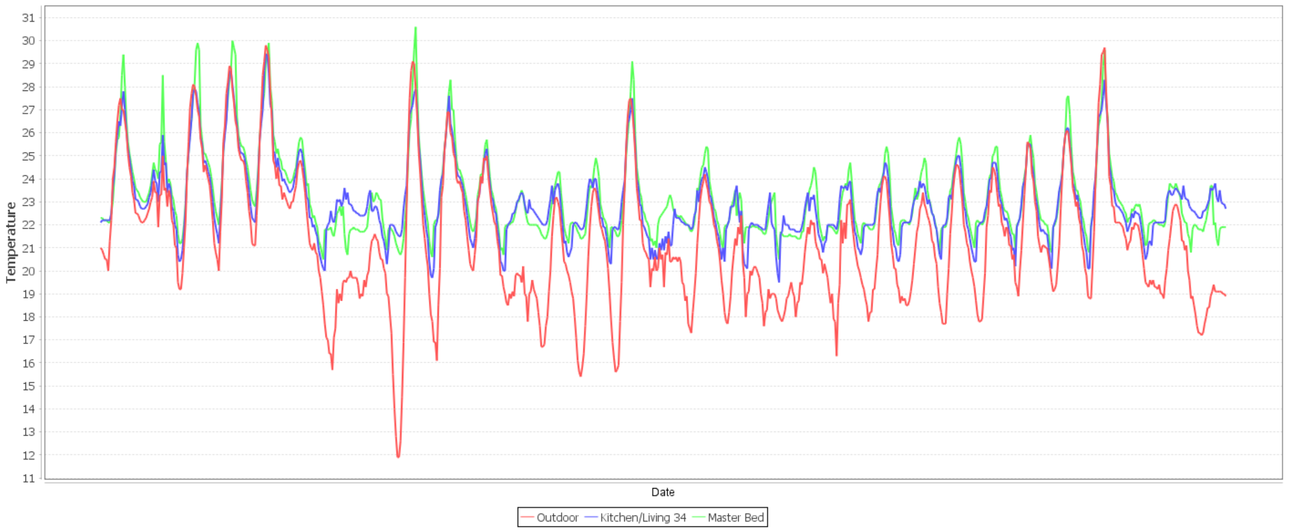

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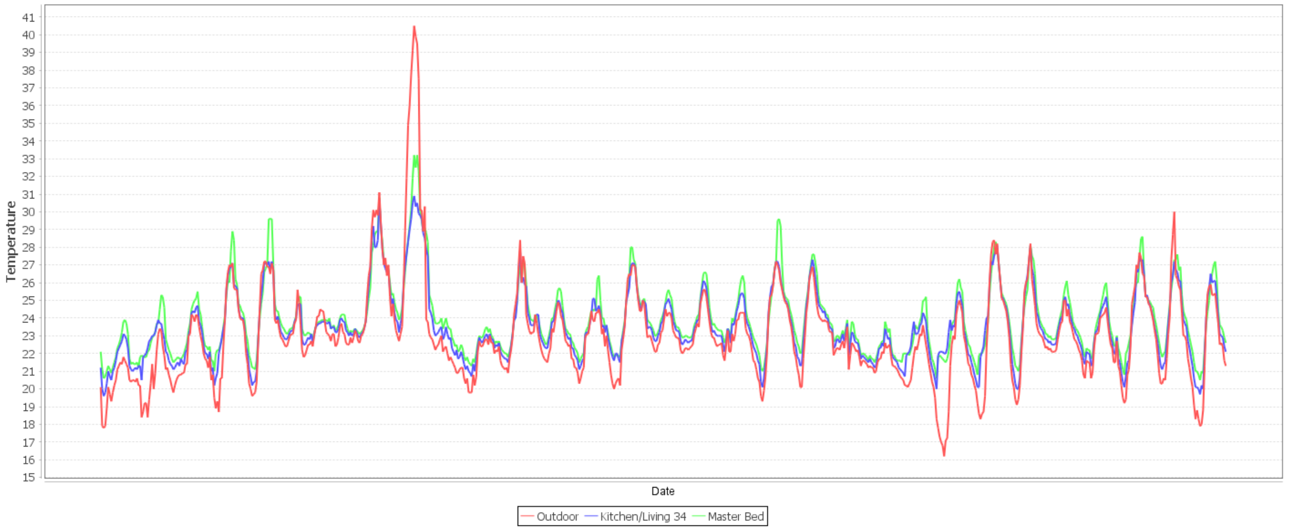

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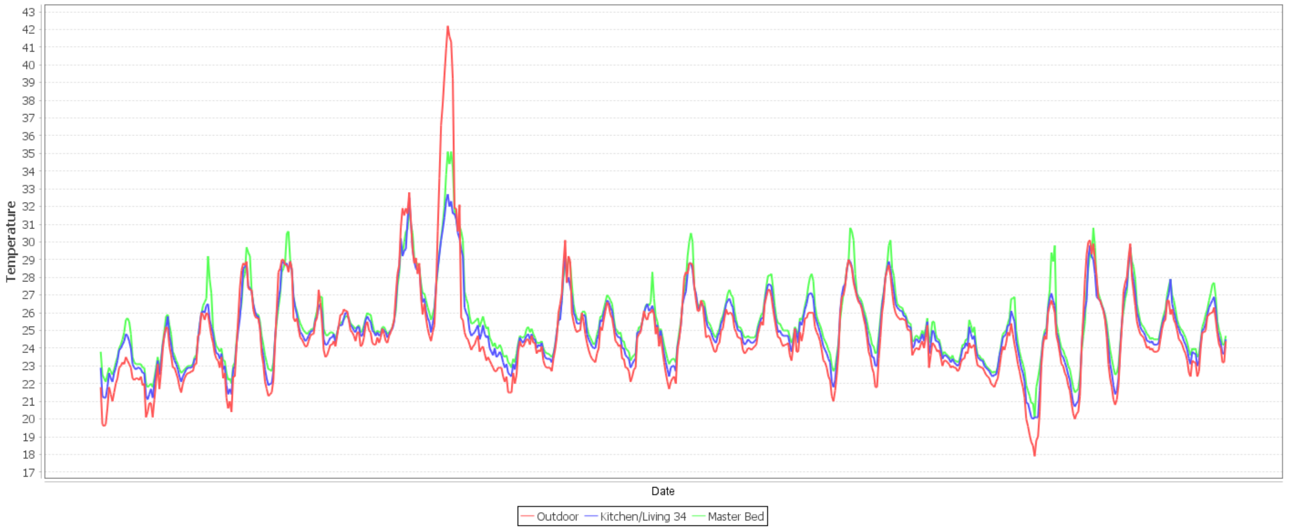
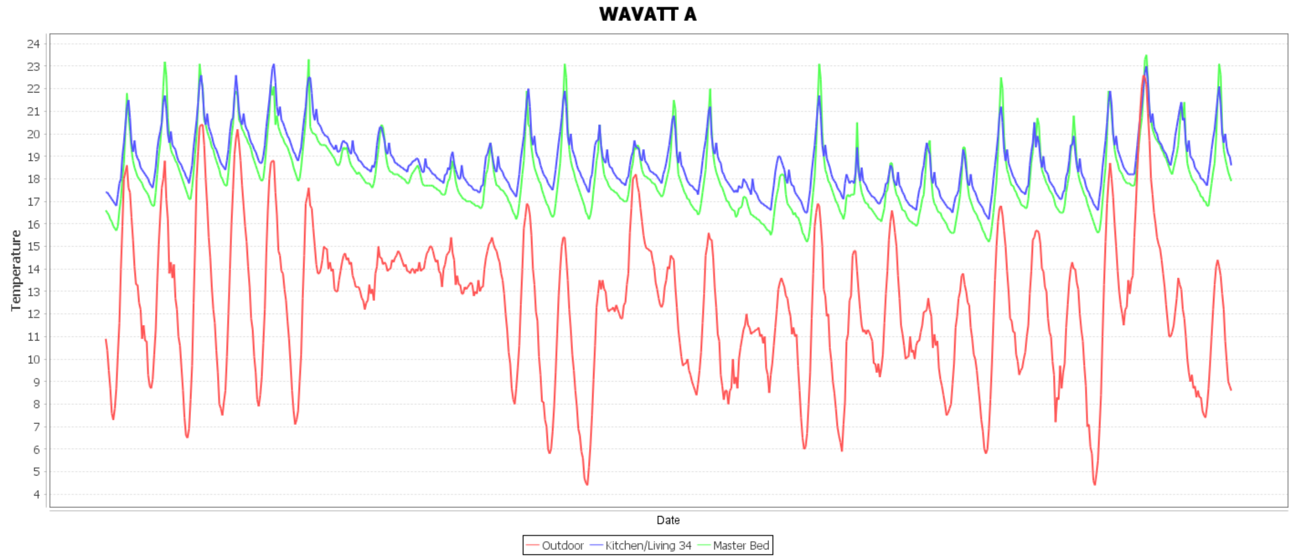


E7 JULY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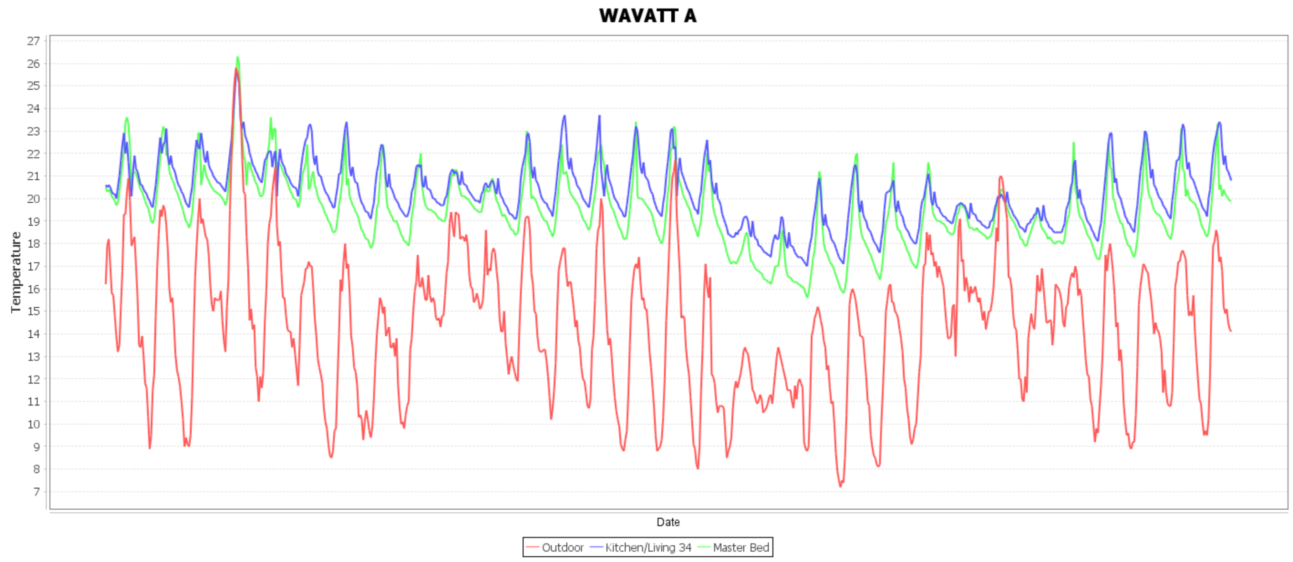
7
6
5
4
Date
Outdoor
Kitchen/Living 34
Master Bed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Temperature
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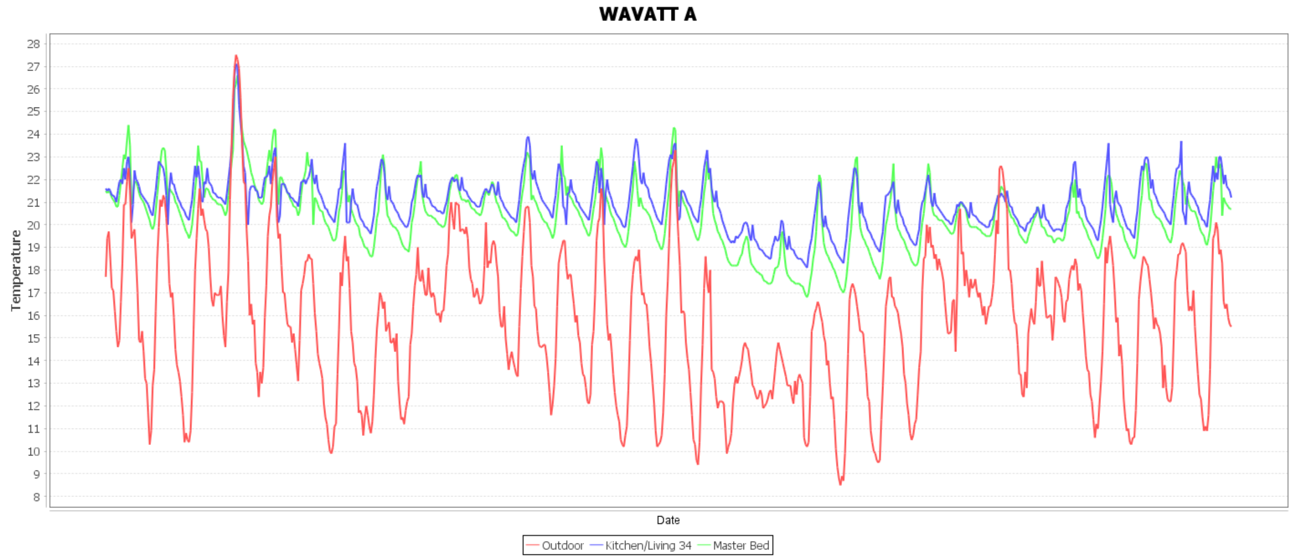
Date
Outdoor
Kitchen/Living 34
Master Bed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Kitchen/Living 34
Master Bed

APPENDIX F

ORIENTATION TESTING RESULTS

F1 ORIENTATION SENSITIVITY

A selection of dwellings from each building type was tested for the effects of changed orientation of the building. Eight cardinal divisions were applied as orientation steps, including the as-certified design orientation and seven other rotations at 45° increments.

Most designs tested demonstrated there were more optimal orientations than the orientation of the actual designs as certified, with only a handful being the best orientation as certified in the Low-rise and Mid-rise buildings.

Selection of the most optimal orientations would be one option to employ in minimising the increases in demand for cooling energy under the future conditions.

In several cases for the Attached, Low-rise, Mid-rise and High-rise building types, some orientations resulted in non-compliance by exceeding the cooling load limit, and would therefore also be the least suited to the issue of increased overheating under the future climate scenarios.

Dwelling	Rotation	Azimuth (°)	Stars	Heating	Cooling	Total	
Unit 1	+45	36	5.9	33.3	19.1	52.3	
	+90	81	5.8	34.4	19.7	54.1	
	+135	126	5.1	41.8	20	64.5	
	+180	171	5.4	39.6	26	59.9	
	+225	216	5.4	40.9	19.2	60	
	+270	261	5.8	36.5	16.6	53.2	Best
	+315	306	5.7	34.7	20	54.8	
	0	351	5.9	30.9	20.8	51.7	As Certified

Figure 6.1 Detached dwelling orientation test results

Dwelling	Rotation	Azimuth (°)	Stars	Heating	Cooling	Total	
Unit A	+45	43	6.6	21.9	22.4	44.3	
	+90	88	6	31.3	19.6	50.9	Best
	+135	133	5	44.3	21.7	66	
	+180	178	4.8	43.7	26.5	70.3	Fail
	+225	223	5.3	36.3	24.6	60.9	
	+270	268	6.6	17.7	26.4	44.1	Fail
	+315	313	6.9	19.3	21.3	40.6	
	0	358	7.1	15.7	21.9	37.6	As Certified
Unit B	+45	43	5.9	27.9	24	51.8	
	+90	88	6.8	19.4	21.7	41	Best
	+135	133	7	15.2	23.7	38.9	
	+180	178	7.2	11.7	24.1	35.8	
	+225	223	7	13.8	24.7	38.5	
	+270	268	6.6	17.7	26.4	44.1	Fail
	+315	313	5.7	26.2	28.8	54.9	Fail
	0	358	5.8	28.6	25.7	54.3	As Certified

Figure 6.2 Attached Dwellings orientation test results

Dwelling	Rotation	Azimuth (°)	Stars	Heating	Cooling	Total	
Unit 1	-45	36	4.7	48.4	22.8	71.2	
	0	81	4.9	44.2	23.3	67.5	As Certified
	+45	126	5.8	31.6	21.8	53.4	
	+90	171	6.5	24.5	20.1	44.7	Best
	+135	216	6.6	22.8	21.4	44.2	
	+180	261	6.1	24.4	25.5	49.9	
	+225	306	5.3	33.6	26.8	60.4	
	+270	351	5.3	38.4	22.7	61.1	
Unit 2	-45	36	4.2	61	21.5	82.5	
	0	81	4.7	43.1	28.7	71.8	As Certified
	+45	126	5.9	24.4	28.7	53.1	
	+90	171	6.9	16.8	23.9	40.7	
	+135	216	5.4	26.1	32.2	58.3	Fail
	+180	261	4.5	39.7	35.3	74.9	Fail
	+225	306	4.2	59.3	24.6	83.8	
	+270	351	4.3	62.4	18.6	81	Best
Unit 3	-45	36	6.4	22.5	23.3	45.8	Best
	0	81	6.5	18.6	26.4	45	As Certified
	+45	126	6.2	19.3	28.9	48.1	
	+90	171	6.1	21.5	28	49.5	
	+135	216	5.4	28.8	30.6	59.4	Fail
	+180	261	4.8	34.5	34.7	69.3	Fail
	+225	306	4.6	38.9	34.3	73.2	Fail
	+270	351	5.8	29	25.4	54.4	
Unit 4	-45	36	5.7	29	26.5	55.5	
	0	81	6.1	28.9	20.5	49.4	As Certified
	+45	126	6.5	27.3	17.2	44.5	
	+90	171	7.2	18.6	17.2	35.8	
	+135	216	7.4	15.6	16.8	32.5	
	+180	261	7.7	14.2	15	29.1	Best
	+225	306	7.1	18.6	19.7	38.3	
	+270	351	6.4	20.8	25.2	45.9	
Unit 5	-45	36	5.6	40.9	15.9	56.7	
	0	81	5.4	32.2	26.1	58.3	As Certified
	+45	126	6.4	20.9	24.7	45.6	
	+90	171	7.3	16.9	17.5	34.5	
	+135	216	6.4	26.5	19.4	45.9	
	+180	261	4.9	33.1	33.3	66.4	Fail
	+225	306	5.1	41.4	23.3	64.8	
	+270	351	5.9	39.4	13.3	52.8	Best
Unit 6	-45	36	6.6	16.1	28.1	44.3	
	0	81	7	13.4	25.3	38.8	Best, As Certified
	+45	126	6.2	18.7	30.2	48.9	Fail
	+90	171	5.4	22.5	36.1	58.6	Fail
	+135	216	5.3	30.1	30.8	60.8	Fail
	+180	261	5.2	33.9	28.5	62.4	
	+225	306	5.1	33.3	31	64.3	
	+270	351	5.6	24.5	31.9	56.4	
Unit 7	-45	36	4.4	39	37.1	76.1	Fail
	0	81	5.2	37	25.3	62.3	As Certified
	+45	126	5.4	36.9	23.2	60.1	
	+90	171	5.6	30.7	26	56.6	
	+135	216	5.8	28.7	24.5	53.2	
	+180	261	6.2	28.8	19.9	48.7	Best
	+225	306	5.1	35.6	29.2	64.8	
	+270	351	4.4	35.7	40.6	76.3	Fail
Unit 8	-45	36	4.3	60.3	19.2	79.4	
	0	81	4.6	45.1	28.9	74	As Certified
	+45	126	5.2	35.6	26.7	62.4	
	+90	171	5.4	36.1	22.8	58.8	
	+135	216	4.4	49	29.8	78.8	Fail
	+180	261	3.9	57.3	35.4	92.7	Fail
	+225	306	3.9	66.8	22.9	89.7	
	+270	351	4.3	65.6	13.7	79.2	Best
Unit 9	-45	36	5.8	24.9	29.3	54.2	
	0	81	6.1	22.8	27.2	50	Best, As Certified
	+45	126	5.2	28.9	33.3	62.2	Fail
	+90	171	4.7	33.1	38.8	71.9	Fail
	+135	216	4.4	39.8	35.5	75.3	Fail
	+180	261	4.5	42.5	32.4	74.8	Fail
	+225	306	4.5	41.7	33.1	74.9	Fail
	+270	351	5	33.2	32.6	65.7	Fail

Dwelling	Rotation	Azimuth (°)	Stars	Heating	Cooling	Total	
Unit 10.1	+45	37	7.4	16.3	17.6	34	
	+90	82	7.7	16.1	13.8	29.8	Best
	+135	127	6.7	25.9	17.3	43.2	
	+180	172	5.4	34.1	24.6	58.6	
	+225	217	4.9	47.8	19	66.8	
	+270	262	5.3	45.5	15.5	61	
	+315	307	5.7	38.4	16.3	54.7	
	0	352	6.4	24.9	20.4	45.2	As Certified
Unit 10.2	+45	37	6.9	23	17.7	40.7	
	+90	82	7.8	16.1	12.4	28.5	Best
	+135	127	7.2	21.2	14.4	35.6	
	+180	172	5.9	31.9	21	52.9	
	+225	217	5	50.3	15.6	65.9	
	+270	262	4.8	56.9	13	69.9	
	+315	307	4.7	57.6	13	70.6	
	0	352	5.2	45.1	17.4	62.5	As Certified
Unit 10.3	+45	37	8.1	6.4	18	24.4	
	+90	82	8.3	6.2	16	22.2	Best
	+135	127	7.7	12	17.5	29.4	
	+180	172	6.7	23.5	19.4	42.9	
	+225	217	5.5	38.5	19.4	57.9	
	+270	262	5.8	36.8	16.8	53.6	
	+315	307	6.4	27.1	18.4	45.5	
	0	352	7.2	15	21.1	36.1	As Certified
Unit 10.4	+45	37	7.1	18.4	19.4	37.8	
	+90	82	7.7	14.2	15.2	29.4	
	+135	127	7.3	17	17.2	34.3	
	+180	172	6.4	23.4	22.2	45.5	
	+225	217	5.8	35.3	19	54.3	
	+270	262	5.6	42.6	14.4	56.9	Best
	+315	307	5.4	44.2	14.5	58.7	
	0	352	5.9	33.8	18.6	52.4	As Certified
Unit 10.5	+45	37	7.8	8.1	20.1	28.1	
	+90	82	0	0	0	0	
	+135	127	7.2	16.4	19.7	36.1	
	+180	172	5.9	29.1	23.9	53	
	+225	217	4.9	47.4	20.3	67.7	
	+270	262	5.3	42.9	17.5	60.4	Best
	+315	307	6.1	30.6	19.6	50.2	
	0	352	7.1	16.3	21.1	37.3	As Certified
Unit 10.6	+45	37	7	20.5	18	38.4	
	+90	82	7.7	15.7	13.6	29.4	
	+135	127	7.4	17.7	16.1	33.7	
	+180	172	6.5	23.2	21.3	44.5	
	+225	217	5.7	38.9	16.3	55.2	
	+270	262	5.3	47.9	13.7	61.6	
	+315	307	5.2	50.6	12.4	63	
	0	352	5.4	40.8	18.5	59.3	As Certified

Figure 6.3 Low-rise dwellings orientation test results

Dwelling	Rotation	Azimuth (°)	Stars	Heating	Cooling	Total	
Unit 0.1	+45	37	7.4	16.3	17.6	34	
	+90	82	7.7	16.1	13.8	29.8	Best
	+135	127	6.7	25.9	17.3	43.2	
	+180	172	5.4	34.1	24.6	58.6	
	+225	217	4.9	47.8	19	66.8	
	+270	262	5.3	45.5	15.5	61	
	+315	307	5.7	38.4	16.3	54.7	
	0	352	6.4	24.9	20.4	45.2	As certified
Unit 0.2	+45	37	6.9	23	17.7	40.7	
	+90	82	7.8	16.1	12.4	28.5	Best
	+135	127	7.2	21.2	14.4	35.6	
	+180	172	5.9	31.9	21	52.9	
	+225	217	5	50.3	15.6	65.9	
	+270	262	4.8	56.9	13	69.9	
	+315	307	4.7	57.6	13	70.6	
	0	352	5.2	45.1	17.4	62.5	As certified
Unit 1.1	+45	37	8.1	6.4	18	24.4	
	+90	82	8.3	6.2	16	22.2	Best
	+135	127	7.7	12	17.5	29.4	
	+180	172	6.7	23.5	19.4	42.9	
	+225	217	5.5	38.5	19.4	57.9	
	+270	262	5.8	36.8	16.8	53.6	
	+315	307	6.4	27.1	18.4	45.5	
	0	352	7.2	15	21.1	36.1	As certified
Unit 1.2	+45	37	7.1	18.4	19.4	37.8	
	+90	82	7.7	14.2	15.2	29.4	
	+135	127	7.3	17	17.2	34.3	
	+180	172	6.4	23.4	22.2	45.5	
	+225	217	5.8	35.3	19	54.3	
	+270	262	5.6	42.6	14.4	56.9	Best
	+315	307	5.4	44.2	14.5	58.7	
	0	352	5.9	33.8	18.6	52.4	As certified
Unit 2.1	+45	37	7.8	8.1	20.1	28.1	
	+90	82	0	0	0	0	
	+135	127	7.2	16.4	19.7	36.1	
	+180	172	5.9	29.1	23.9	53	
	+225	217	4.9	47.4	20.3	67.7	
	+270	262	5.3	42.9	17.5	60.4	Best
	+315	307	6.1	30.6	19.6	50.2	
	0	352	7.1	16.3	21.1	37.3	As certified
Unit 2.2	+45	37	7	20.5	18	38.4	
	+90	82	7.7	15.7	13.6	29.4	
	+135	127	7.4	17.7	16.1	33.7	
	+180	172	6.5	23.2	21.3	44.5	
	+225	217	5.7	38.9	16.3	55.2	
	+270	262	5.3	47.9	13.7	61.6	
	+315	307	5.2	50.6	12.4	63	Best
	0	352	5.4	40.8	18.5	59.3	As certified
Unit 2.3	+45	37	4.8	42.6	27.5	70.1	
	+90	82	4.4	49.3	26.3	75.7	
	+135	127	4.9	43.2	23	66.2	
	+180	172	6.3	27.4	20.5	47.8	
	+225	217	6.8	20	21	41	
	+270	262	7.1	17.6	20.3	37.9	Best
	+315	307	0	0	0	0	
	0	352	5.8	28.9	24.4	53.3	As certified
Unit 3.1	+45	37	6.1	30.7	19.5	50.1	
	+90	82	6.6	24.9	19.3	44.2	Best
	+135	127	6.3	26.7	21.3	47.9	
	+180	172	5.9	29.9	21.9	51.9	
	+225	217	4.8	41.7	27.7	69.4	
	+270	262	4.5	43.7	31.1	74.8	Fail
	+315	307	0	0	0	0	
	0	352	5.4	34	24.1	58.1	As certified
Unit 3.2	+45	37	4.7	40.2	30.8	71	Fail
	+90	82	4.4	43.1	35	78.1	Fail
	+135	127	4.8	38.3	31.4	69.7	Fail
	+180	172	0	0	0	0	
	+225	217	0	0	0	0	
	+270	262	0	0	0	0	
	+315	307	0	0	0	0	
	0	352	5.8	30.3	24	54.3	As certified
Unit 4.1	+45	37	5.4	38.3	21.7	60	
	+90	82	5.6	35.8	20.6	56.4	Best
	+135	127	5	38.2	27.1	65.3	
	+180	172	4.8	36.1	32.8	68.9	Fail
	+225	217	5.1	38	26.5	64.5	
	+270	262	0	0	0	0	
	+315	307	0	0	0	0	
	0	352	5.2	40.4	21.9	62.3	As certified

Figure 6.4 Mid-rise dwellings orientation test results

Dwelling	Rotation	Azimuth (°)	Stars	Heating	Cooling	Total	
Unit 10.7	+45	37	4.8	42.6	27.5	70.1	
	+90	82	4.4	49.3	26.3	75.7	
	+135	127	4.9	43.2	23	66.2	
	+180	172	6.3	27.4	20.5	47.8	
	+225	217	6.8	20	21	41	
	+270	262	7.1	17.6	20.3	37.9	Best
	+315	307	0	0	0	0	
	0	352	5.8	28.9	24.4	53.3	As Certified
Unit 10.8	+45	37	6.1	30.7	19.5	50.1	
	+90	82	6.6	24.9	19.3	44.2	Best
	+135	127	6.3	26.7	21.3	47.9	
	+180	172	5.9	29.9	21.9	51.9	
	+225	217	4.8	41.7	27.7	69.4	
	+270	262	4.5	43.7	31.1	74.8	Fail
	+315	307	0	0	0	0	
	0	352	5.4	34	24.1	58.1	As Certified
Unit 10.9	+45	37	4.7	40.2	30.8	71	Fail
	+90	82	4.4	43.1	35	78.1	
	+135	127	4.8	38.3	31.4	69.7	Fail
	+180	172	0	0	0	0	
	+225	217	0	0	0	0	
	+270	262	0	0	0	0	
	+315	307	0	0	0	0	
	0	352	5.8	30.3	24	54.3	As Certified
Unit 10.10	+45	37	5.4	38.3	21.7	60	
	+90	82	5.6	35.8	20.6	56.4	
	+135	127	5	38.2	27.1	65.3	
	+180	172	4.8	36.1	32.8	68.9	Fail
	+225	217	5.1	38	26.5	64.5	
	+270	262	0	0	0	0	
	+315	307	0	0	0	0	
	0	352	5.2	40.4	21.9	62.3	As Certified
Unit 10.11	+45	37	5.4	38.3	21.7	60	
	+90	82	5.6	35.8	20.6	56.4	
	+135	127	5	38.2	27.1	65.3	
	+180	172	4.8	36.1	32.8	68.9	Fail
	+225	217	5.1	38	26.5	64.5	
	+270	262	0	0	0	0	
	+315	307	0	0	0	0	
	0	352	5.2	40.4	21.9	62.3	As Certified
Unit 10.12	+45	37	5.4	38.3	21.7	60	
	+90	82	5.6	35.8	20.6	56.4	
	+135	127	5	38.2	27.1	65.3	
	+180	172	4.8	36.1	32.8	68.9	Fail
	+225	217	5.1	38	26.5	64.5	
	+270	262	0	0	0	0	
	+315	307	0	0	0	0	
	0	352	5.2	40.4	21.9	62.3	As Certified
Unit 10.13	+45	37	5.4	38.3	21.7	60	
	+90	82	5.6	35.8	20.6	56.4	
	+135	127	5	38.2	27.1	65.3	
	+180	172	4.8	36.1	32.8	68.9	Fail
	+225	217	5.1	38	26.5	64.5	
	+270	262	0	0	0	0	
	+315	307	0	0	0	0	
	0	352	5.2	40.4	21.9	62.3	As Certified

Figure 6.5 High-rise dwellings orientation test results