7 Star Upgrade Analysis

Orientation Case Studies

Sustainability Victoria

Contents

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Introduction

By 2056 Victoria's population is expected to reach 11.2 million and to support this growth is it projected that 2.3 million new dwellings will need to be built.[1] Through measures such as increasing the star rating and overall efficiency of homes, the Victorian building and construction industry is set to make significant headway toward our State's ambitious net zero emissions targets.

In line with the Victorian Government's Climate Change Strategy – a roadmap to net zero emissions and a climate resilient Victoria by 2050, updated efficiency requirements for new residential buildings are included in the 2022 edition of the National Construction Code. These updated requirements include:

- An increase in the minimum efficiency performance requirement for the building shell (insulation, window glazing etc) from 6 to 7 stars* out of a possible 10
- Introduction of a 'Whole of Home' approach to managing the energy use of specific fixed appliances (hot water, heating and cooling, lighting and pool and spa pumps)

About this Upgrade Analysis

This document has been prepared to provide designers, builders, architects, thermal performance assessors and students, with the confidence and insights needed to affordably and effectively transition from building 6 to 7 star homes by optimising the design and orientation for passive solar principles.

Included within are 10 comparative case studies of class 1a, residential detached and semi-detached dwellings that represent a cross section of existing volume home designs demonstrating the impact that orientation has on the thermal performance rating. This research shows that achieving good orientation from the start of the design process is the key to saving on future construction costs when building to 7 stars.

Sustainability Victoria sought the support of an independent NatHERS Assessor – Filter ESD to analyse and document the changes required to go from a 6 to 7 star NatHERS rating for the same design over different orientations. Each case study provides information on the homes best and worst orientation, required upgrades and upgrade costs. The upgrades were costed by an independent quantity surveyor in February 2022.

Please note:

- The transition from 6 to 7 stars has been achieved without changing the floor plan or the exterior look and feel of the homes. This included no changes to exterior cladding material, or the colour of the roof. Window size was also unaffected in all but two designs.
- The homes were analysed in 8 different orientations, with the best and worst orientations for each home highlighted in the data provided.
- All plans were rated using the FirstRate5 House Energy Rating Software.

1 Victoria in Future 2019 - Population and household projections 2016 to 2056 report https://www.planning.vic.gov.au/__data/assets/pdf_file/0032/332996/Victoria_in_Future_2019.pdf

7 Star Design Considerations

Careful design and orientation will make the most effective contribution to meeting the increased standards. If design is considered early in the process of a new home build, achieving 7 stars can be done without significant additional costs or changes in materials and construction, but will still deliver a more comfortable and resilient home that saves the residents money on energy bills.

While good orientation can help to cost-effectively meet a 7 star thermal rating, it is not a mandatory requirement. There is flexibility to achieve the NatHERS rating through a range of approaches on blocks of varying size and orientation.

Good design that factors in the local climate and appropriate thermal building materials are important factors, particularly for apartments or volume estates where orientation is more variable.

Orientation and Shading

A home with optimal orientation has its main living areas (and largest windows) facing north or north-east. This ensures that the home's most used areas make use of the sun all year round.

Homes with the main living spaces oriented to the south or west can struggle to achieve a 7 star NatHERS rating without significant costs to upgrade insulation and glazing and can be less comfortable to live in due to having dark or glary living spaces.

Utility areas such as bathrooms, laundries and garages can act as buffer zones and should be located on the west and south sides of the home.

To support a good orientation, you should consider building on the south, east or west boundaries. If this is not possible, at least place the home close to the southern boundary. This gives you more space to put your living areas on the north and helps to avoid windows in less favourable orientations.

On blocks with difficult orientations, the use of north facing clearstory windows can enable the main living areas to benefit from the winter sun.

Shading is key to maximising on the benefits of good orientation. Without proper shading a home can overheat in summer, this makes it difficult to achieve a 7 star NatHERS rating. Shading is often provided through appropriately sized eaves, which cut out the harshest summer sun, but allow the sunlight to enter in winter when the sun is lower in the sky.

The use of operable shading devices such as external blinds and awnings can benefit designs where eaves are difficult such as on west facing or ground floor windows. Two case studies in this analysis required external awning blinds to achieve 7 stars in their worst orientation due to large expanses of west facing glazing.

Orientation also contributes to cross ventilation. In areas with prevailing winds to the north and south, such as in Melbourne, operable windows on the northern and southern facades allow for natural cross ventilation. This effect creates a breeze through the house allowing for passive cooling after a hot summer's day.

When it comes to alfresco areas, special consideration needs to be given to their placement. A large covered alfresco off a north-facing living area prevents the living room from receiving adequate sun in winter – as it provides too much shading. This can result in high heating demand and a reduced energy rating despite an optimal orientation.

A previous analysis of 15 homes constructed during Sustainability Victoria's zero net carbon homes pilot showed:

- Floorplans or layouts that are sensitive to orientation can have a difference of up to a 1.2 star NatHERS rating.
- On average a difference of 0.5 stars NatHERS was observed between the best and worst orientation.
- Some designs have only a 0.1 star difference between the worst and best orientation due to significant self-shading caused by building elements such as alfresco dining areas and complex built forms. In Victoria, these homes perform poorly across all orientations as they don't benefit from the winter sun.

Insulation

Enhanced insulation offers improvements to annual energy use, thermal comfort levels and noise reduction. Factoring in an increase to the level of insulation in the roof, external walls and internal walls is a cost-effective way toward achieving a 7 star NatHERS rating.

Increasing insulation levels becomes especially necessary when changes to passive solar design such as shading, and orientation are not able to sufficiently increase the home's rating.

Typical insulation upgrades include:

- Upgrading ceiling insulation from R4.1/R5.0 to R5.0/R6.0 batts and in some cases including reflective foil sarking or R1.3 anti-con foil blankets
- Upgrading external wall insulation from R1.5/2.0 to R2.5/2.7 batts
- Upgrading insulation between the home and the garage and adding or upgrading insulation in internal walls around wet areas.

Building designers and NatHERS assessors need to work together to ensure the specified insulation is detailed correctly on the plans, particularly when specifying higher levels of ceiling insulation. Perimeter batts are likely to be required to enable sufficient ventilation and should be detailed in the plans and modelled as part of the NatHERS rating. Dropping the ceiling level below the height of the base plate is one strategy to maintain appropriate ventilation with higher R value ceiling insulation.

As increased R values are specified to achieve higher star ratings, it is increasingly vital that insulation is installed with careful attention to detail. Incorrect or inappropriate installation will significantly decrease performance and could lead to issues with condensation. For instance, failure to butt all ends and edges of batts to give a snug fit could result in 5% of the ceiling area not being covered, this can reduce the effective R value of R4.0 insulation to R2.2.

External frame corners and interior exterior wall intersections are often missed when insulating a home, leading to increased thermal bridging and potential condensation issues. If using standard framing techniques these external cavities should be fully insulated prior to installing any building wraps. Advanced framing techniques such as open corners which allow for continuous insulation are a good way to reduce thermal bridging and prevent condensation forming in the home.

Windows

Windows are a key change to increasing a design's star rating and upgrading from single-glazed to double-glazed can have the biggest impact on both cost and energy efficiency.

Most standard home designs can successfully be taken from 6 to 7 stars without reducing window size, however, where site constrains mean that implementing passive solar design principles is not practical, or you want to use larger windows areas, high performance glazing allows you to meet minimum energy efficiency requirements without compromising on other aspects of the design.

Windows consist of glazing and framing, and both contribute to the energy efficiency of the window. The extent of heat loss through glazing is measured by the U value. The lower the U value the better. The U values for double glazing can vary considerably depending on the size of the air gap between the panes, the type of gas filling used, the use of low emittance coatings and the material of the window frame. Higher performing windows framed in timber, uPVC and thermally broken aluminium help to reduce issues related to condensation and should be considered if project budgets allow.

The Window Energy Rating Scheme gives a star rating to a window's glazing and frame energy performance, making it easier to compare different windows and decide which is best for your needs.

Typical window upgrades used throughout this analysis include:

- Upgrading from single glazing to a combined use of single and double-glazed windows: start by upgrading the largest living zone windows first as these have the biggest impact on star rating.
- Upgrading so all windows are double glazed: not only does this help the star rating but it also contributes to better temperature control, increased comfort and reduced condensation on cold days
- Upgrading from standard double glazing with an air gap to double glazing with an argon gap
- Upgrading to low-e glazing
- Upgrading to high performance windows with thermally broken frames particularly for larger living room windows (this upgrade is not featured in this documents case studies; all windows were specified with standard aluminium frames)

Impact of Orientation on Upgrade Cost

The analysis of 10 class 1a, residential detached and semi-detached dwelling case studies demonstrates the impact orientation has on the thermal performance rating and associated upgrade cost of a design. While it is possible to upgrade from 6 to 7 stars in each of the case study homes' worst orientation, achieving optimal orientation from the start of the design process is the key to saving on future construction costs when building to 7 stars and beyond.

Upgrade costings used in this analysis have been completed by an independent quantity surveyor and reflect the material cost only. Labour costs have not been considered as in most cases this is not impacted due to the upgrades replacing materials already getting installed. Some case studies where additional roof sarking or internal wall insulation is added will have minor additional labour costs not reflected in this analysis.

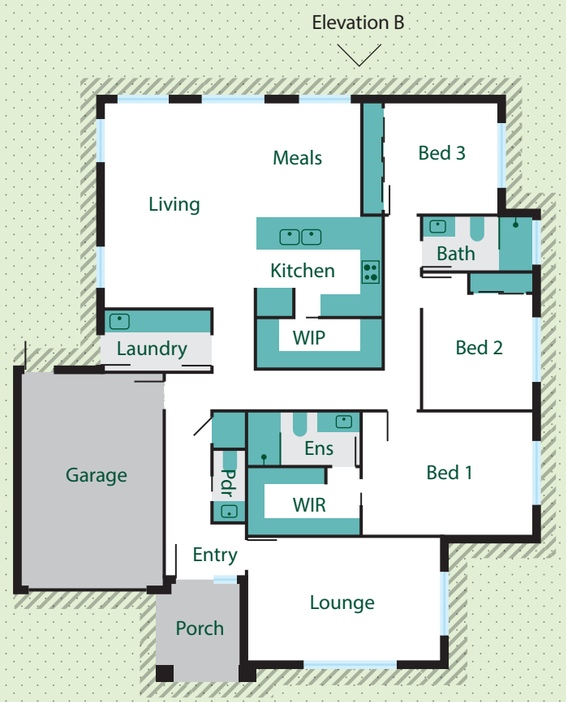
The costs to upgrade to 7 stars in the best and worst orientation was assessed against a baseline case of 6 stars in the best orientation for each home. The costs to upgrade in the best orientation are between $19.85 per m^2 and $48.22 per m^2 whereas the in the worst orientation the costs are between $40.58 per m^2 and $71.52 per m^2. On average the upgrade cost in the worst orientation was $10,939 or $51 per m^2 compared to $7383 or $22 per m^2 in the best orientation.

The average cost difference between the best and worst orientation at 7 stars was $3555 demonstrating the benefits of designing new homes for optimal orientation

Case Study 1 | **Location** Craigieburn | **Climate zone** 60

A four-bed, one-living, single storey detached home

Best orientation | **Worst orientation** | **Difference:** 0.6 stars



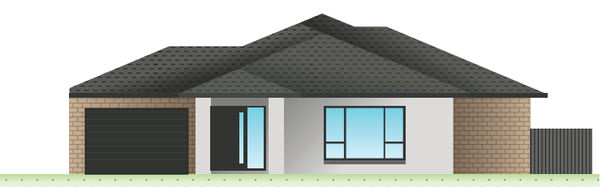
Wall insulation upgrade cost*
Best orientation: $730
Worst orientation: $780

Roof insulation upgrade cost*
Best orientation: $430
Worst Orientation: $1340

Window upgrade cost*
Best orientation: $2680
Worst orientation: $6190

*Please note that all costs have been rounded up to nearest ten

Shaded by eaves



Elevation A

Elevation B

Adapted from original plans and elevations by VCON Homes. Not to scale.

Results of the Analysis

No changes were made to the original floorplan, building fabric areas and window sizes.

Description

Design Features	A compact single storey detached dwelling, with four bedrooms and one main living space. Eaves throughout. Glazing approx. 23% of net conditioned floor area (NCFA).
Size (m^2)	House: 157 / Garage: 36
Orientation and thermal performance notes	When the primary living space faces north, this home achieves a 6 star rating with basic thermal specifications. Eaves provide protection from high-angle summer sun, while permitting winter solar gain through windows and glazed doors. In this optimal orientation, only modest upgrades are required to reach 7 stars. However, thermal performance suffers if the living space doesn't receive enough free solar heating; when the living space faces south, the rating drops by 0.6 stars.
Impact of orientation	0.6 star NatHERS

Construction

Floors	EPS Waffle pod slab on ground (R0.6 avg.)
Walls	Brick veneer
Roof and ceiling	Tiled roof with flat ceiling
Windows and doors	Standard aluminium

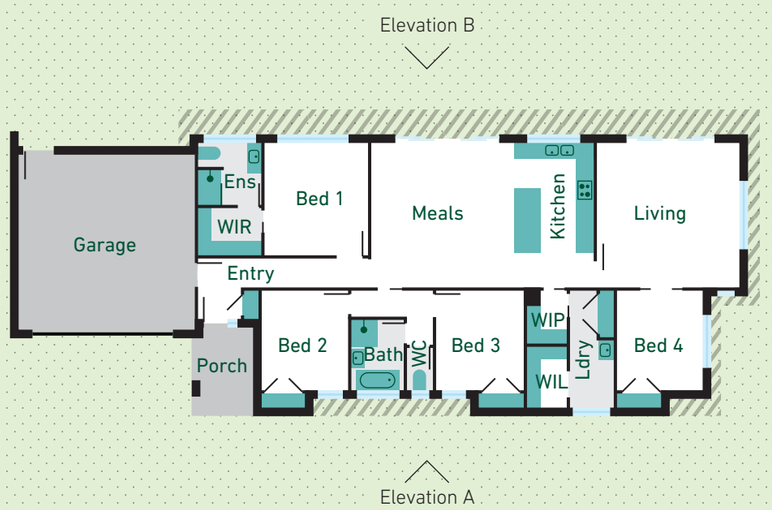
	Baseline	Best Orientation	Worst Orientation
Star Rating	6.1 (best orientation)	**7.0**	**7.0**
Insulation & Glazing	**Initial specifications**	**Changes required**	**Changes required**
External walls	R1.5	**R2.5**	**R2.5**
Internal walls	R1.5 to Garage only	**R1.5 to Garage, Laundry & Bath**	**R2.0 to Garage, Laundry & Bath**
Ceiling	R3.5	**R5.0**	**R6.0**
Roof	Nil	**Foil sarking**	**Foil sarking**
Windows and glazed doors	SG to all	**DG to Kitchen/Meals/Living; SG to rest of house**	**DG to all**
Upgrade cost total**	Baseline	**$3800**	**$8300**

**Please note that costs have been rounded up to nearest $100

Case Study 2 | **Location** Kyneton | **Climate zone** 66

A four-bed, two-living, single storey detached home

Best orientation | **Worst orientation** | **Difference:** 1.2 stars



Plan

Wall insulation upgrade cost*
Best orientation: $810
Worst orientation: $2250

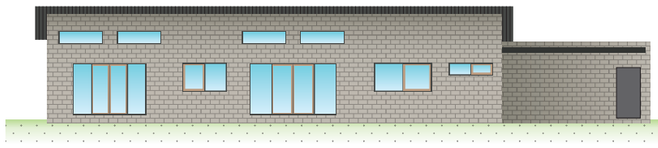
Roof insulation upgrade cost*
Best orientation: $440
Worst Orientation: $1700

Window upgrade cost*
Best orientation: $7410
Worst orientation: $9600

*Please note that all costs have been rounded up to nearest ten

Shaded by eaves

Elevation A



Elevation B

Adapted from original plans and elevations by SJD Homes. Not to scale.

Results of the Analysis

No changes were made to the original floorplan, building fabric areas and window sizes.

Description

Design Features	A single storey detached dwelling with four bedrooms and two living spaces. The elongated floorplan has raked ceilings, high-level clerestory windows and generous eaves on the intended north elevation. Glazing approx. 28% of NCFA.
Size (m^2)	House: 162 / Garage: 41
Orientation and thermal performance notes	This home was designed with its living areas and main bedroom positioned to the north. Glazing is concentrated on this elevation to exploit beneficial winter solar gain, while deep eaves provide shading in summer. In this optimal orientation, only basic thermal specifications and upgrades are required to reach 6 or 7 stars. However, performance drops significantly if orientation is sub-optimal – up to 1.2 stars. To reach 7 stars in the worst orientation, substantial investment in thermal specification upgrades is required.
Impact of orientation	1.2 star NatHERS

Construction

Floors	EPS Waffle pod slab on ground (R0.6 avg.)
Walls	Brick veneer Timber feature cladding on studs
Roof and ceiling	Metal roof with flat and raked ceilings (as noted on plans)
Windows and doors	Standard aluminium

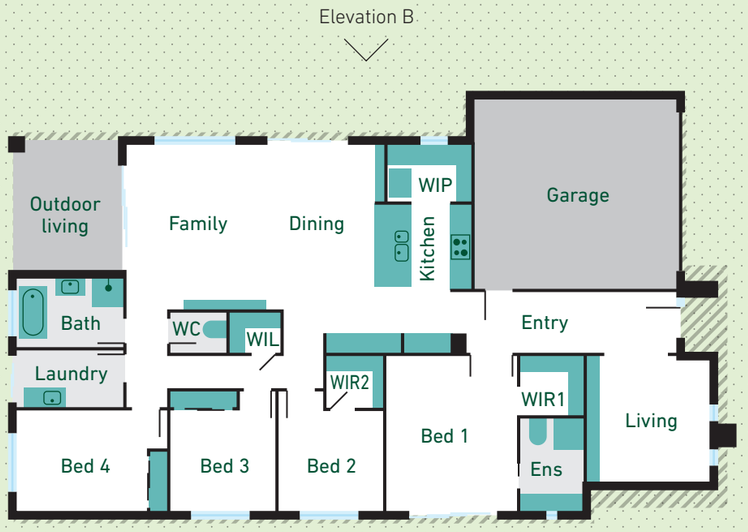
	Baseline	Best Orientation	Worst Orientation
Star Rating	6.0 (best orientation)	**7.1**	**7.0**
Insulation & Glazing	**Initial specifications**	**Changes required**	**Changes required**
External walls	R1.5	**R2.0**	**R2.7**
Internal walls	R1.5 to Garage only	**R2.0 to Garage only**	**R2.5 to Garage, Laundry, WIL, Bath & WC**
Ceiling	R3.5	**R5.0**	**R6.0**
Roof	Nil	**Foil sarking**	**R1.3 reflective roof blanket**
Windows and glazed doors	SG to all	**DG to Kitchen/ Meals & Living; SG to rest of house**	**DG low-e to all**
Upgrade cost total**	Baseline	**$8700**	**$13600**

**Please note that costs have been rounded up to nearest $100

Case Study 3 | **Location** Mickleham | **Climate zone** 60

A four-bed, two-living, single storey detached home

Best orientation N | **Worst orientation** | **Difference:** 0.4 stars



Plan

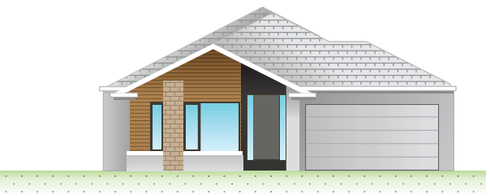
Wall insulation upgrade cost*
Best orientation: $940
Worst orientation: $940

Roof insulation upgrade cost*
Best orientation: $1030
Worst Orientation: $2870

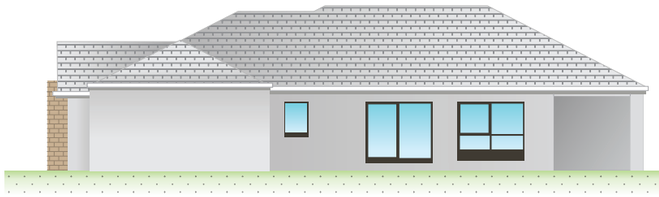
Window upgrade cost*
Best orientation: $6860
Worst orientation: $9080

*Please note that all costs have been rounded up to nearest ten

Shaded by eaves



Elevation A



Elevation B

Adapted from original plans and elevations by Metricon Homes. Not to scale.

Results of the Analysis

No changes were made to the original floorplan, building fabric areas and window sizes.

Description

Design Features	A single storey detached dwelling, with four bedrooms and two living spaces. The main Kitchen / Living space connects to a small covered outdoor living area. Eaves to the entry and front living room only. Glazing approx. 27% of NCFA.
Size (m^2)	House: 188 / Garage: 37 / Outdoor living: 13
Orientation and thermal performance notes	This home performs best with the primary living area facing north. In this orientation, northern solar gain is maximised, while the covered outdoor living area provides some shade to the west. But with most windows unshaded, and a relatively high proportion of glazing to floor area, this home is more thermally vulnerable than the previous case studies. This is evident in the higher thermal specifications needed to reach 6 and 7 stars. With living areas located at opposite ends of the home, there is only modest variation (0.4 stars) from the best to worst orientation.
Impact of orientation	0.4 star NatHERS

Construction

Floors	EPS Waffle pod slab on ground (R0.6 avg.)
Walls	Brick veneer Timber feature cladding on studs
Roof and ceiling	Tiled roof with flat and raked ceilings (as noted on plans)
Windows and doors	Standard aluminium (except timber framed entry door / sidelight)

	Baseline	Best Orientation	Worst Orientation
Star Rating	6.1 (best orientation)	**7.0**	**7.0**
Insulation & Glazing	**Initial specifications**	**Changes required**	**Changes required**
External walls	R2	**R2.5**	**R2.5**
Internal walls	R1.5 to Garage only	**R2.5 to Garage, Laundry & Bath**	**R2.5 to Garage, Laundry & Bath**
Ceiling	R5	**R6.0**	**R6.0**
Roof	Foil sarking	**Foil sarking**	**Air-Cell reflective insulation**
Windows and glazed doors	DG to Kitchen/ Dining/ Living; SG to rest of house	**DG to All**	**DG low-e to Kitchen/ Dining/ Living; DG to rest of house**
Upgrade cost total**	Baseline	**$8900**	**$12,900**

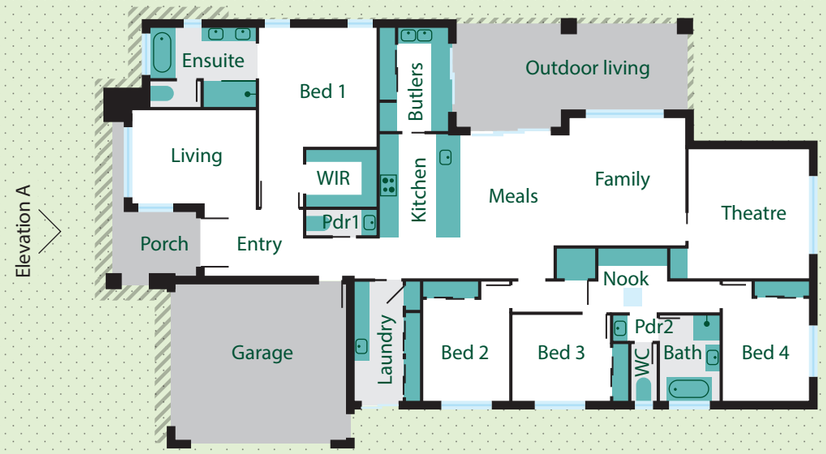
**Please note that costs have been rounded up to nearest $100

Case Study 4 | **Location** Officer | **Climate zone** 62

A four-bed, three-living, single storey home

Best orientation | **Worst orientation** | **Difference:** 0.2 stars

Elevation B



Plan

Wall insulation upgrade cost*
Best orientation: $2060
Worst orientation: $2060

Roof insulation upgrade cost*
Best orientation: $440
Worst Orientation: $1750

Window upgrade cost*
Best orientation: $8740
Worst orientation: $8740

*Please note that all costs have been rounded up to nearest ten

Shaded by eaves

Elevation A

Elevation B

Adapted from original plans and elevations by SJD Homes. Not to scale.

Results of the Analysis

No changes were made to the original floorplan, building fabric areas and window sizes.

Description

Design Features	A large single storey detached dwelling, with four bedrooms and three living spaces. The main Kitchen / Living area connects to a large covered outdoor living space. Eaves to the front rooms only. Glazing approx. 22% of NCFA.
Size (m^2)	House: 234 / Garage: 36 / Outdoor living: 28
Orientation and thermal performance notes	This design does not particularly capitalise on any one orientation. The home performs best when the primary living area faces north – despite significant overshadowing of north-facing glazing by the covered outdoor living area. While such shading is useful in summer, the depth of this structure also obstructs beneficial solar gain during winter. In this orientation, other living spaces (the Theatre and Living room) receive morning and afternoon sun from the east and west. This combination of design features means there is very little variation from best to worst orientation. Significant upgrades to insulation and glazing performance are required to achieve 7 stars across all orientations..
Impact of orientation	0.2 star NatHERS

Construction

Floors	EPS Waffle pod slab on ground (R0.6 avg.)
Walls	Brick veneer
Roof and ceiling	Metal roof with flat ceiling
Windows and doors	Standard aluminium

	Baseline	Best Orientation	Worst Orientation
Star Rating	6.0 (best orientation)	**7.0**	**7.0**
Insulation & Glazing	**Initial specifications**	**Changes required**	**Changes required**
External walls	R2	**R2.7**	**R2.7**
Internal walls	R2.0 to Garage, Laundry, Bath & WC	**R2.5 to Garage, Laundry, Bath & WC**	**R2.5 to Garage, Laundry, Bath & WC**
Ceiling	R5	**R5.0**	**R6.0**
Roof	Foil sarking	**R1.3 reflective roof blanket**	**R1.3 reflective roof blanket**
Windows and glazed doors	DG to Kitchen/ Meals/ Family; SG to rest of house	**G low-e to Kitchen/ Meals/ Family; DG to rest of house**	**DG low-e to Kitchen/ Meals/ Family; DG to rest of house**
Upgrade cost total**	Baseline	**$11,300**	**$12,600**

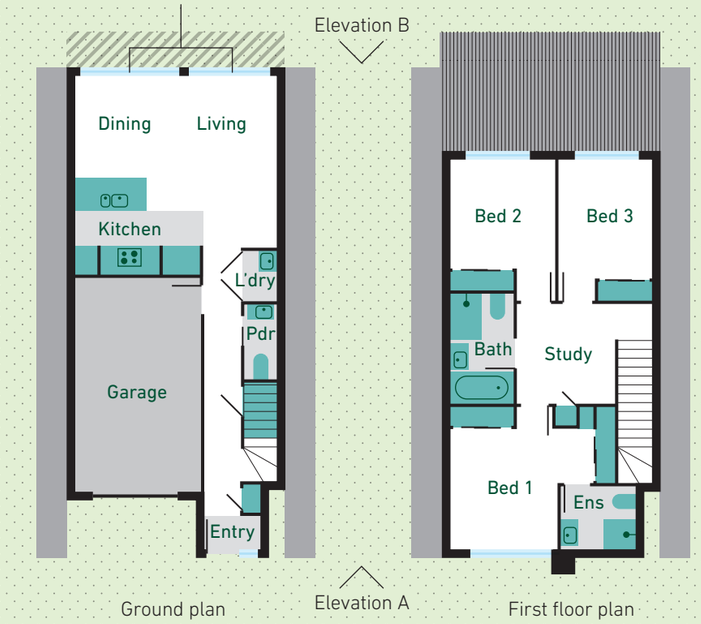
**Please note that costs have been rounded up to nearest $100

Case Study 5 | **Location** Braybrook | **Climate zone** 60

A three-bed, one-living, double storey attached townhouse

Best orientation | **Worst orientation** | **Difference:** 0.8 stars

These windows reduced in width for worst orientation, 7 Star version (-2sqm total)



Wall insulation upgrade cost*
Best orientation: $400
Worst orientation: $400

Roof insulation upgrade cost*
Best orientation: $510
Worst Orientation: $670

Window upgrade cost*
Best orientation: $4140
Worst orientation: $4600

*Please note that all costs have been rounded up to nearest ten

Adjacent units

Shaded by eaves

Elevation A

Elevation B

Adapted from original plans and elevations by Stockland. Not to scale.

Results of the Analysis

No changes were made to the original floorplan and building fabric areas, however the window sizes for the living areas were reduced by 2 sqm in the worst orientation.

Description

Design Features	A two storey attached townhouse with three bedrooms and one main living space. Long boundary walls adjoin the neighbouring dwellings. Glazing approx. 22% of NCFA, confined to the short ends of the dwelling. Horizontal eave above the Kitchen / Living glazing only.
Size (m^2)	House: 118 / Garage: 23
Orientation and thermal performance notes	This dwelling performs best with the living area facing north. In this orientation, the eave provides good summer shading, while allowing beneficial winter solar gain. The high proportion of glazing to floor area in the main living space increases thermal vulnerability and makes glazing performance and shading particularly important. To achieve 6 stars in any orientation, the living area windows and doors need to be double glazed. In the worst orientation, when the living area faces west, this thermal vulnerability is exacerbated. Winter heating demand increases, while west-facing rooms suffer from summer overheating due to low-angle direct sun in the afternoon. External vertical blinds are required to shade west-facing glazing. To achieve 7 stars in the worst orientation, a small glazing area reduction is required to improve thermal performance in the living space.
Impact of orientation	0.8 star NatHERS

Construction

Floors	Ground storey: EPS Waffle pod slab on ground (R0.6 avg.) Upper storey: Timber framed
Walls	Ground storey: Brick veneer Upper storey: Rendered 75mm EPS cladding or fibre cement cladding Boundary party walls: Double stud with fire separation panel
Roof and ceiling	Metal roof with flat ceiling
Windows and doors	Standard aluminium (except timber framed entry door / sidelight)

	Baseline	Best Orientation	Worst Orientation
Star Rating	6.1 (best orientation)	**7.0**	**7.0**
Insulation & Glazing	**Initial specifications**	**Changes required**	**Changes required**
Upper floors	R2.0 External/ Over Garage	**R2.0 External/ Over Garage**	**R2.5 External/ Over Garage**
External walls	R2	**R2.5**	**R2.5**
Internal walls	R1.5 to Garage only	**R2.5 to Garage only**	**R2.5 to Garage only**
Party Walls	R2.5	**R2.5**	**R2.5**
Ceiling	R4.0	**R5.0**	**R6.0**
Roof	Foil sarking	**R1.3 reflective roof blanket**	**R1.3 reflective roof blanket**
Windows and glazed doors	DG to Kitchen/ Dining/ Living; SG to rest of house	**DG low-e to Kitchen/ Dining/ Living; DG to rest of house**	**DG low-e to all; Reduce Dining / Living glazing by Approx. 2sqm**
Adjustable Shading	N/A	**N/A**	**External blinds to all west-facing windows**
Upgrade cost total**	Baseline	**$5100**	**$5800**

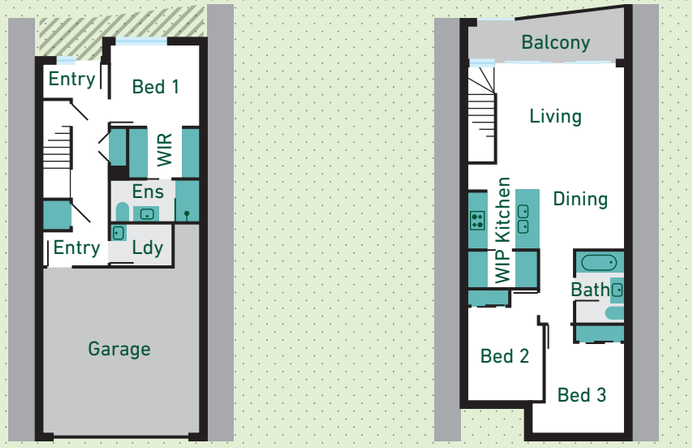
**Please note that costs have been rounded up to nearest $100

Case Study 6 | **Location** Altona | **Climate zone** 60

A three-bed, one-living, 'upside down' double storey townhouse

Best orientation N | **Worst orientation** NZ | **Difference:** 0.7 stars

Elevation A



Ground floor plan | Elevation B | First floor plan

Wall insulation upgrade cost*
Best orientation: $1040
Worst orientation: $1200

Roof insulation upgrade cost*
Best orientation: $610
Worst Orientation: $760

Window upgrade cost*
Best orientation: $1500
Worst orientation: $7640

*Please note that all costs have been rounded up to nearest ten

Adjacent units

Shaded by eaves

Elevation A

Elevation B

Adapted from original plans and elevations by Stockland. Not to scale.

Results of the Analysis

No changes were made to the original floorplan, building fabric areas and window sizes.

Description

Design Features	A two storey attached townhouse with three bedrooms and one main living space. An 'upside-down' arrangement with the Kitchen / Living area on the upper storey, connecting to a covered balcony. Long boundary walls adjoining neighbouring dwellings. Glazing approx. 17% of NCFA.
Size (m^2)	House: 120 / Garage: 38 / Outdoor living: 11
Orientation and thermal performance notes	This house performs best with the living area and master bedroom facing north. The large glazed doors of the living area permit plenty of winter solar gain, while the roofed balcony provides good shade in summer. The balcony structure also creates shade for the windows below. In this optimal orientation, only basic thermal specifications and upgrades are required to reach 6 or 7 stars. In the worst orientation, with the living area facing west, both winter heating and summer cooling demand increase. In this orientation, the horizontal shade of the balcony is insufficient for low-angle afternoon summer sun, so external vertical blinds are required to reduce overheating in west-facing rooms.
Impact of orientation	0.7 star NatHERS

Construction

Floors	Ground storey: EPS Waffle pod slab on ground (R0.6 avg.) Upper storey: Timber framed
Walls	Ground storey: Brick veneer Upper storey: Fibre cement cladding Boundary party walls: Double stud with fire separation panel
Roof and ceiling	Metal roof with flat ceiling
Windows and doors	Standard aluminium (except timber framed entry door / sidelight)

	Baseline	Best Orientation	Worst Orientation
Star Rating	6.2 (best orientation)	**7.0**	**7.0**
Insulation & Glazing	**Initial specifications**	**Changes required**	**Changes required**
Upper floors	R2.0 Over Garage	**R2.0 Over Garage**	**R2.0 Over Garage**
External walls	R1.5	**R2.5**	**R2.5**
Internal walls	R1.5 to Garage only	**R2.0 to Garage only**	**R2.5 to Garage and Laundry**
Party Walls	R1.5	**R2.0**	**R2.5**
Ceiling	R3.5	**R5.0**	**R5.0**
Roof	Nil	**Foil sarking**	**R1.3 reflective roof blanket**
Windows and glazed doors	SG to all	**DG to Kitchen/ Dining/ Living; SG to rest of house**	**DG to all**
Adjustable Shading	N/A	**N/A**	**External blinds to west-facing habitable windows**
Upgrade cost total**	Baseline	**$3200**	**$7700**

**Please note that costs have been rounded up to nearest $100

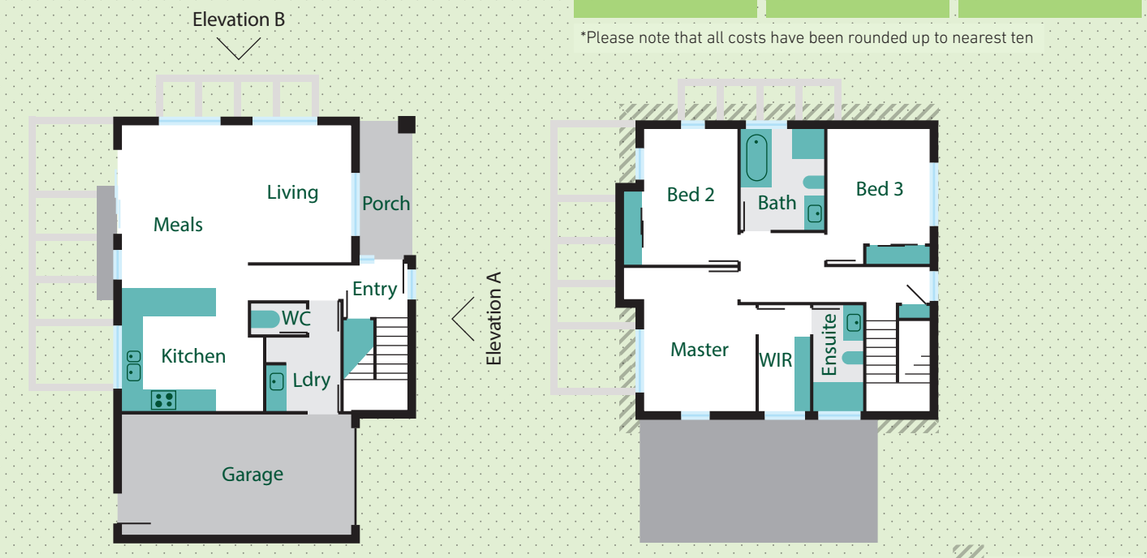
Case Study 7 | **Location** Pakenham | **Climate zone** 62

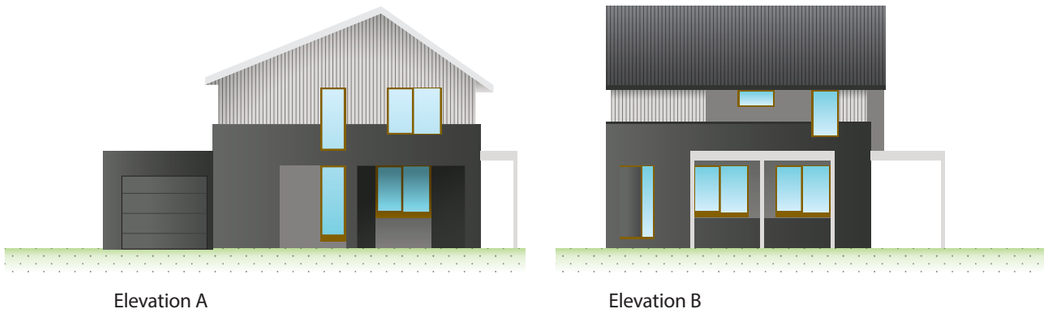
A three-bed, one-living, double storey detached townhouse

Best orientation	**Worst orientation**	**Difference:** 0.3 stars

Wall insulation upgrade cost*	**Roof insulation upgrade cost***	**Window insulation upgrade cost***
Best orientation: $90 Worst orientation: $1170	Best orientation: $160 Worst orientation: $160	Best orientation: $7860 Worst orientation: $10,750

*Please note that all costs have been rounded up to nearest ten





Adapted from original plans and elevations by SJD Homes. Not to scale.

Results of the Analysis

No changes were made to the original floorplan, building fabric areas and window sizes.

Description

Design Features	A compact two storey detached townhouse with three bedrooms and one main living space. Eaves to the upper storey only. Glazing approx. 30% of NCFA.
Size (m^2)	House: 140 / Garage: 25
Orientation and thermal performance notes	This home has a high proportion of glass to floor area, particularly in the open-plan kitchen / living area, where windows and glazed doors face three different directions. Because of this design feature, the main living area receives good solar gain across a range of orientations, so there is low variation (0.3 stars) between best and worst. This home performs best when the Meals / Living area faces north, and the Kitchen faces west. In its worst orientation, significant upgrades to insulation and glazing specifications are required to reach 7 stars. (Note: the uncovered pergola structures could provide good seasonal shading with deciduous plants, but this is not included in a regulatory energy rating.)
Impact of orientation	0.3 star NatHERS

Construction

Floors	Ground storey: EPS Waffle pod slab on ground (R0.6 avg.) Upper storey: Timber framed
Walls	Ground storey: Brick veneer Upper storey: Rendered fibre cement cladding or grooved timber board
Roof and ceiling	Metal roof with flat ceiling
Windows and doors	Standard aluminium

	Baseline	**Best Orientation**	**Worst Orientation**
Star Rating	6.1 (best orientation)	**7.0**	**7.0**
Insulation & Glazing	**Initial specifications**	**Changes required**	**Changes required**
Upper floors	R2.0 where external	**R2.0 where external**	**R2.5 where external**
External walls	R2.5	**R2.5**	**R2.7**
Internal walls	R2.0 to Garage only	**R2.0 to Garage and Bath**	**R2.0 to Garage and Bath**
Ceiling	R5.0	**R5.0**	**R6.0**
Roof	Foil sarking	**R1.3 reflective roof blanket**	**R1.3 reflective roof blanket**
Windows and glazed doors	SG to all	**DG to all**	**DG low-e to Kitchen/ Meals/ Living; DG to rest of house**
Upgrade cost total**	Baseline	**$8100**	**$12,000**

**Please note that costs have been rounded up to nearest $100

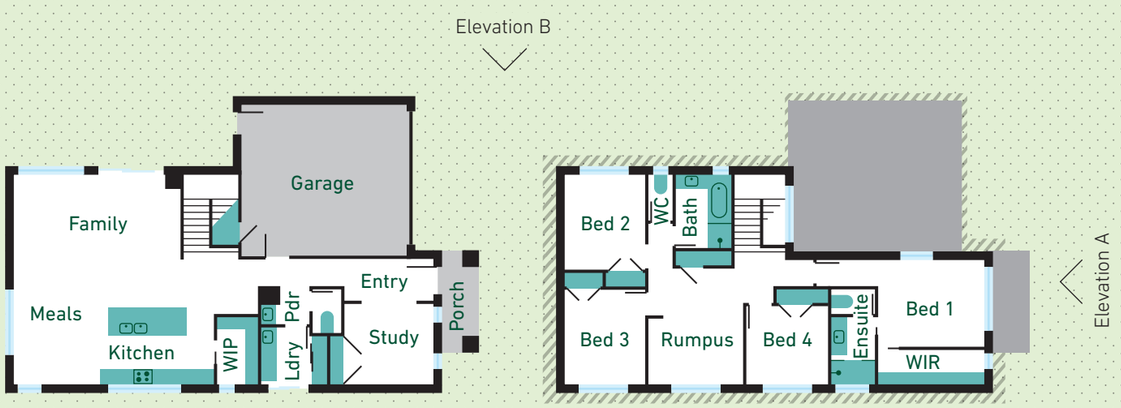
Case Study 8 | **Location** Ballarat | **Climate zone** 66

A four-bed, three-living, double storey home

Best orientation	Worst orientation	Difference: 0.2 stars

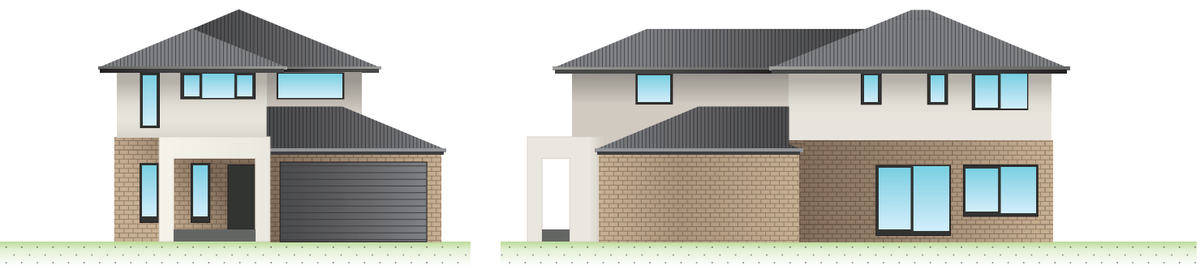
Wall insulation upgrade cost*	Roof insulation upgrade cost*	Window insulation upgrade cost*
Best orientation: $1340 Worst orientation: $1340	Best orientation: $170 Worst orientation: $170	Best orientation: $5180 Worst orientation: $9600

*Please note that all costs have been rounded up to nearest ten



Ground floor plan

First floor plan



Elevation A

Elevation B

Adapted from original plans and elevations by SJD Homes. Not to scale.

Results of the Analysis

No changes were made to the original floorplan, building fabric areas and window sizes.

Description

Design Features	A two storey detached dwelling with four bedrooms and three living spaces. Eaves to the upper storey only. Glazing approx. 24% of NCFA.
Size (m^2)	House: 208 / Garage: 37
Orientation and thermal performance notes	This home performs best when the largest windows and doors of the primary living space face north. However, with multiple living areas facing various directions, there is only modest variation between the best and worst orientations of this home. While the upper storey windows are sheltered by eaves, the windows to the main living space on the ground floor would benefit from some external shading to reduce summer solar gain. Double glazing is required to all living area windows in order to reach 7 stars; in the worst orientation, this upgrade applies to the whole house.
Impact of orientation	0.2 star NatHERS

Construction

Floors	Ground storey: EPS Waffle pod slab on ground (R0.6 avg.) Upper storey: Timber framed
Walls	Ground storey: Brick veneer Upper storey: Rendered 75mm EPS cladding
Roof and ceiling	Metal roof with flat ceiling
Windows and doors	Standard aluminium

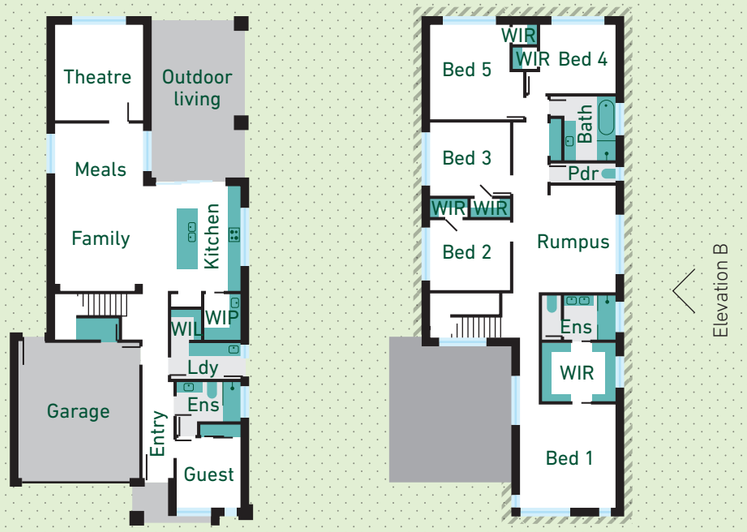
	Baseline	Best Orientation	Worst Orientation
Star Rating	6.1 (best orientation)	**7.0**	**7.0**
Insulation & Glazing	**Initial specifications**	**Changes required**	**Changes required**
Upper floors	N/A	**N/A**	**N/A**
External walls	R2.0	**R2.5**	**R2.5**
Internal walls	R1.5 to Garage only	**R2.5 to Garage, Laundry, Bath & WC**	**R2.5 to Garage, Laundry, Bath & WC**
Ceiling	R5.0	**R5.0**	**R5.0**
Roof	Foil sarking	**R1.3 reflective roof blanket**	**R1.3 reflective roof blanket**
Windows and glazed doors	SG to all	**DG to Kitchen/ Meals/ Family and Rumpus; SG to rest of house**	**DG to all**
Upgrade cost total**	Baseline	**$6700**	**$11,100**

**Please note that costs have been rounded up to nearest $100

Case Study 9 | **Location** Cranbourne | **Climate zone** 62

A six-bed, three-living, double storey detached dwelling with large outdoor space

Best orientation | **Worst orientation** | **Difference:** 0.3 stars



Wall insulation upgrade cost*
Best orientation: $0
Worst orientation: $0

Roof insulation upgrade cost*
Best orientation: $330
Worst Orientation: $330

Window upgrade cost*
Best orientvation: $11,410
Worst orientation: $13,890

*Please note that all costs have been rounded up to nearest ten

Shaded by eaves

Elevation A

Elevation B

Adapted from original plans and elevations by SJD Homes. Not to scale.

Results of the Analysis

No changes were made to the original floorplan, building fabric areas and window sizes.

Description

Design Features	A large two storey detached dwelling, with six bedrooms and three living spaces. The main Kitchen / Living area connects to a large outdoor living space covered by the upper storey. Eaves to the upper storey only. Glazing approx. 20% of NCFA.
Size (m^2)	House: 295 / Garage: 36 / Outdoor living: 31
Orientation and thermal performance notes	This home has multiple living areas, with glazing facing in various directions. This partly explains why there is very little thermal performance variation between the best and worst orientations of this home. The other contributing features is the covered outdoor living area, which creates significant overshadowing for the adjoining windows and glazed doors of the primary living space. While such extensive shading may be beneficial in summer, Melbourne is a heating-dominated climate, and this design feature restricts opportunity for passive solar heating during cooler months.
Impact of orientation	0.3 star NatHERS

Construction

Floors	Ground storey: EPS Waffle pod slab on ground (R0.6 avg.) Upper storey: Timber framed
Walls	Ground storey: Brick veneer Upper storey: Rendered 75mm EPS cladding
Roof and ceiling	Metal roof with flat ceiling
Windows and doors	Standard aluminium

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	Baseline	Best Orientation	Worst Orientation
Star Rating	6.1 (best orientation)	**7.0**	**7.0**
Insulation & Glazing	**Initial specifications**	**Changes required**	**Changes required**
Upper floors	R2.0 where external	**R2.0 where external**	**R2.0 where external**
External walls	R2.5	**R2.5**	**R2.5**
Internal walls	R2.0 to Garage, Laundry, Bath & Powder	**R2.0 to Garage, Laundry, Bath & Powder**	**R2.0 to Garage, Laundry, Bath & Powder**
Ceiling	R5.0	**R5.0**	**R5.0**
Roof	Foil sarking	**R1.3 reflective roof blanket**	**R1.3 reflective roof blanket**
Windows and glazed doors	SG to all	**DG to all**	**DG low-e to Kitchen/ Meals/ Family; DG to rest of house**
Upgrade cost total**	Baseline	**$11,400**	**$13,900**

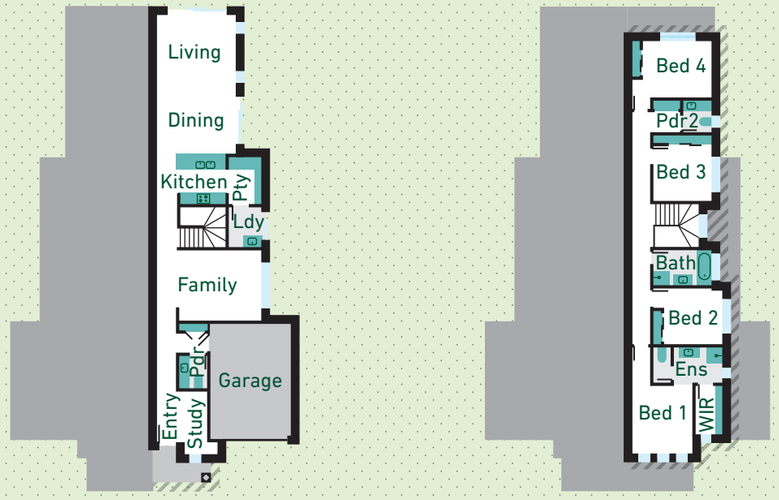
**Please note that costs have been rounded up to nearest $100

Case Study 10	**Location** Essendon	**Climate zone** 60

Four-bed, two-living, semi-detached and mirrored double storey townhouses

Best orientation N | **Worst orientation** N | **Difference:** 1.1 stars

Elevation B



Ground floor plan

Elevation A

First floor plan

Wall insulation upgrade cost*
Best orientation: $1590
Worst orientation: $1810

Roof insulation upgrade cost*
Best orientation: $210
Worst Orientation: $210

Window upgrade cost*
Best orientation: $4830
Worst orientation: $7800

*Please note that all costs have been rounded up to nearest ten

Shaded by eaves

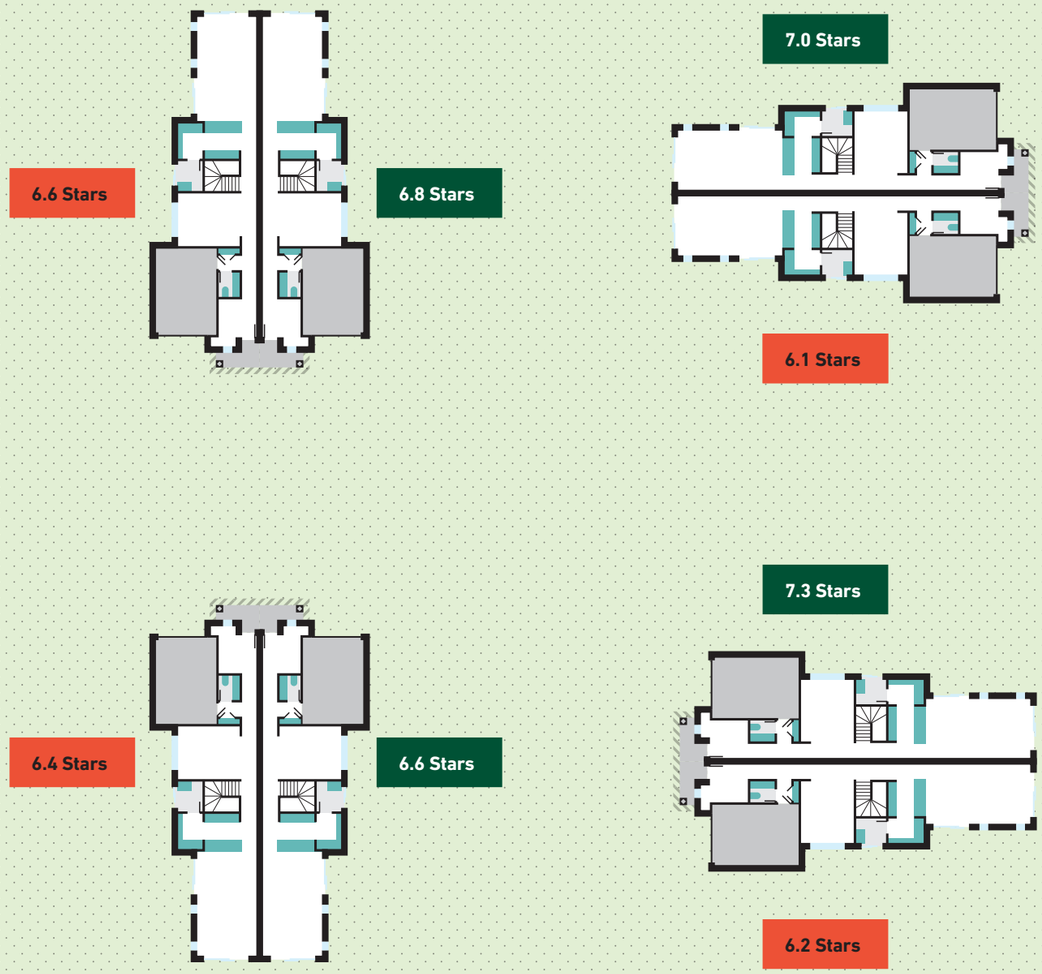
Elevation A

Elevation B

Adapted from original plans and elevations by Metricon Homes. Not to scale.

Orientation Analysis

Further orientation analysis based on the original '7 star best' specifications show the rating results for the mirrored floor plan at different site orientations. This analysis highlights the impact of orientation, and the need for specification upgrades in order for both townhouses to achieve similar ratings.



Case Study 10 (cont.) | **Location** Essendon | **Climate zone** 60

Four-bed, two-living, semi-detached and mirrored double storey townhouses (cont.)

Results of the Analysis

No changes were made to the original floorplan and building fabric areas, however window sizes were reduced by a total of 2.6 m^2 in total for all the living/dining and kitchen areas in the worst orientation.

Description

Design Features	A large two storey semi-detached dwelling, with four bedrooms and two living spaces. Designed as a dual-occupancy subdivision, the floor plan is mirrored along the central party wall. Eaves to the upper storey only. Glazing approx. 22% of NCFA. NOTE: The star rating and specifications in the table below relate to the right-hand floorplan, as indicated in the plans.
Size (m^2)	House: 210 / Garage: 28
Orientation and thermal performance notes	The mirrored semi-detached floor plan means that one whole elevation of the home does not have any windows. This has a significant contribution to the performance of the home across various orientations. This home performs best when the long external elevation faces north. This allows for good solar gain into the main living spaces, as well as some upper storey bedrooms. The short ends of the dwelling receive morning and afternoon sun from the east and west, and there is no south-facing glass. If the floorplan is reoriented or flipped to the south, performance drops considerably, and significant specification upgrades are required to achieve the same star rating. In the worst orientation, beneficial northern solar gain is obstructed by the adjoining dwelling, creating high artificial heating demand. In order to reach 7 stars in this orientation, selective glazing area reductions are required to improve thermal performance in the living spaces.
Impact of orientation	1.1 star NatHERS

Construction

Floors	Ground storey: EPS Waffle pod slab on ground (R0.6 avg.) Upper storey: Timber framed
Walls	Ground storey: Brick veneer Upper storey: Weatherboard cladding Boundary party walls: Double stud with fire separation panel
Roof and ceiling	Tiled roof with flat ceiling
Windows and doors	Standard aluminium

	Baseline	Best Orientation	Worst Orientation
Star Rating	6.0 (best orientation)	**7.0**	**7.0**
Insulation & Glazing	**Initial specifications**	**Changes required**	**Changes required**
Upper floors	R2.0 Over Garage	**R2.0 Over Garage**	**R2.5 Over Garage**
External walls	R1.5	**R2.5**	**R2.7**
Internal walls	R1.5 to Garage only	**R2.0 to Garage, Laundry, Bath & Powder**	**R2.0 to Garage, Laundry, Bath & Powder**
Party Walls	R1.5	**R2.5**	**R2.5**
Ceiling	R5.0	**R6.0**	**R6.0**
Roof	Foil sarking	**Foil sarking**	**Foil sarking**
Windows and glazed doors	SG to all	**DG to Kitchen / Dining / Living & Family; SG to rest of house**	**DG low-e to all; Reduce Kitchen / Dining / Living & Family glazing by approx. 2.6sqm**
Upgrade cost total**	Baseline	**$6700**	**$11,435**

**Please note that costs have been rounded up to nearest $100

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