Case studies

Case studies

The following drawings are for four case studies of typical building types in New Zealand. Each of them has been thermally modelled in ECCHO (Energy Carbon Calculator for Homes) in three different climate zones to assess what specification will be required to meet both 6 Homestar and 8 Homestar levels of performance in each climate.

The specifications produced show one way of achieving the required performance levels. Every project will need to be individually modelled to achieve the best outcomes for the available budget.

Further build-ups and assemblies are detailed in the Assemblies chapter.

The case studies have been selected to show real world scenarios and therefore are not necessarily perfectly orientated for optimal performance.

How to use this section

Performance considerations - These show the thought process around the building performance based on the initially specified building fabric, prior to making any decisions on upgrades to the specification.

Drawings - 3D views, plans, elevations and sections have been provided for each typology to give an overview of the design.

Specification table - This shows the selected specifications to meet Homestar 6 and 8 in three different climate zones for these specific designs, on these specific sites. These are provided to give an example starting point for similar projects in each climate, however each project will need to be tailored individually.

Results - This shows the specific ECCHO results for each typology, climate and star rating for comparison.

Costing - This provides high level pricing of each typology, isolating the performance related upgrades and the cost increase from building code minimum for Homestar 6 and Homestar 8, in the three climate zones.

What if I want to do better?

These case studies and specifications work for these unique designs, in the specified sites and climates, to show an example of how to achieve certain performance levels. This doesn't mean the same specifications would have the same results for a different building in the same site, or the same building on a different site.

Energy modelling is a holistic approach to building performance, and is all about balance. If we increase the window performance we could decrease the insulation, and achieve similar performance for less cost. The only way to judge this is to model your design, then assess the results and heat balance chart to see where the changes should be.

Performance considerations for all case studies

When designing for performance, decisions must be made earlier in the design process than in a traditional work flow. Building fabric, space for ventilation systems, joinery size and shading; all can impact the overall performance and aesthetic of the building, and each has a differing impact.

The following key points are ordered in level of impact on the overall performance, specifically when undertaking the design and energy modelling for the following four case studies:

1. Design is the best tool to optimize the thermal performance, as upgrading a specification once a design is well resolved can be costly and less effective. All four case studies in this guide have been designed with energy balance in mind, but they have not been oriented to optimise thermal performance. This methodology is chosen to represent an average scenario and inform realistic baseline specification decisions.

2. Specifications are about the balance of how all performance related items work together as one system. ECCHO is the critical tool to inform the best balance amongst insulation, thermal bridges, windows, ventilation and airtightness.

3. Climate always has a significant impact on the ease/difficulty of achieving the targeted rating. Overall, a warmer climate is easier to achieve the heating demand and total electricity demand target than colder climates. However, the overheating target can often trigger additional upgrades on glazing and shading devices in warmer climates.

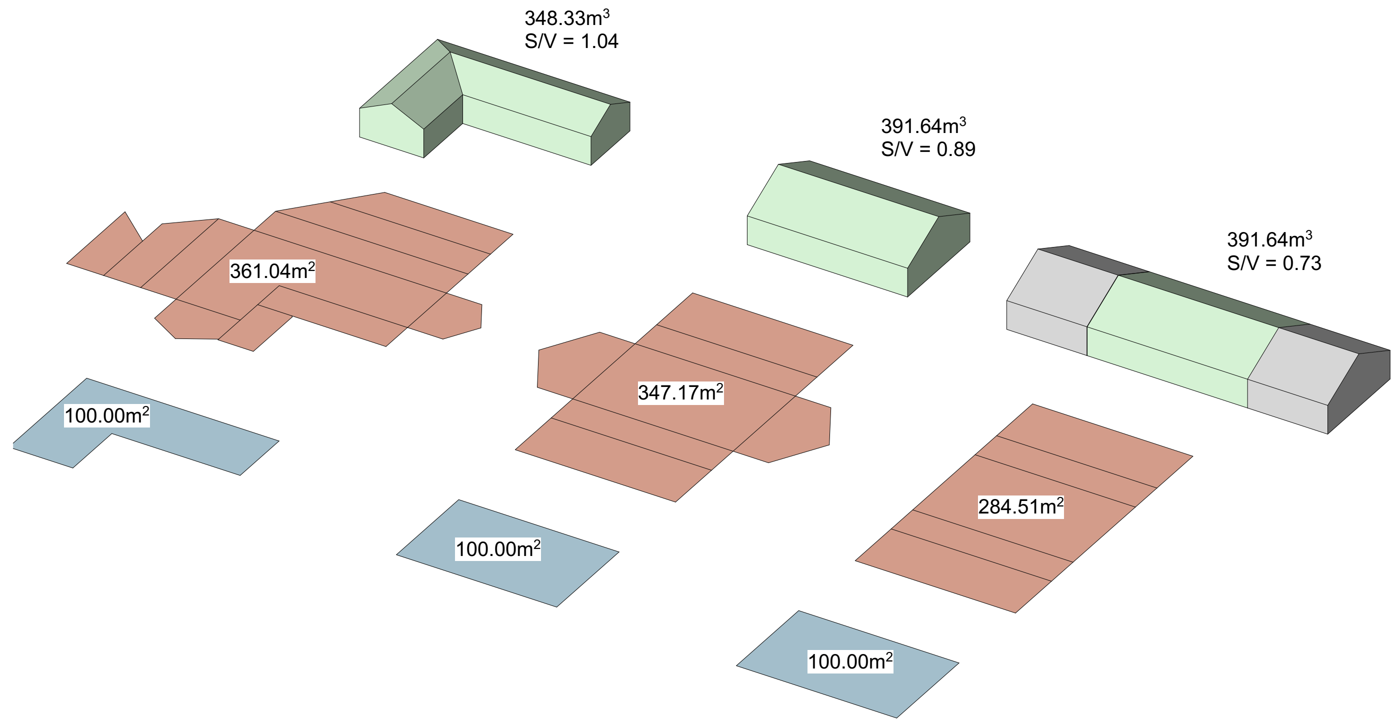
4. Homestar 6 accommodates a larger portion of “standard practices” such as traditional framing with timber corner and dwangs, window installation flush with cladding, as well as ECCHO default window frame, front door panel and glazing specs. This is due to requiring lower performance levels, which means we can accommodate more heat loss.

5. Homestar 8 requires a larger portion of “best practices” such as 2 stud corners without dwangs, recessed window installation, supplier’s specific window frames, front door panel, and glazing data. This is due to requiring higher performance levels, which means we need to be more specific in our decisions with less margin for error.

6. Window and glazing are nearly always the most imprtant contributors to both heating demand and the potential for overheating. Implementing fit for purpose solutions for each individual project is critically important, but is also a relatively easy alteration - changing the frames or glass will have minimal impact on the form or overall design. Using default values in ECCHO is suitable when there is a medium to large margin on both heating demand and overheating. However, obtaining exact window and glazing data from manufacturers is required to represent the real performance. When overheating potential is high, specific selection of low-e glass is required.

7. Wall insulation is nearly always the second most influential system on heating demand. Smart framing solutions such as removing dwangs and using two stud corners to optimise the wall framing is an easy and cost-effective solution to improve thermal performance. Other barriers for external wall upgrade can be high. For example, the next level from conventional 140mm framing wall is to add a 45mm insulated service cavity, which triggers additional labour and external bracing.

8. Roof insulation normally has a small impact on performance. This is due to the relatively high requirement by the building code H1. Having roof insulation less than R6.6 can sometimes provide a



The more complex the form of the building, the harder it is to achieve higher levels of performance as there is more heat loss area compared to the volume or floor area. These three buildings have the same floor area, but adding a bend in the form increases the heat loss area by 4%, and increases the surface to volume ratio (S/V) from 0.89 to 1.04 - a 16.8% increase.

Making the building part of a terrace decreases the surface area, as only the areas not bordering other units count as heat loss area, so achieving higher performance is even easier.

better overall balance. Roof insulation less than R5.2 is generally not encouraged because it is likely to cause both higher heating demand and overheating.

9. Suspended floor insulation normally has a small impact on performance. Utilise the maximum depth of the floor joists and full fill with insulation, include a wind-washing membrane layer to the underside, and ensure ground cover is specified - a mandatory minimum.

10. Slab insulation normally has a small impact on performance if it is fully insulated to the edges and underside. In waffle pod slab systems, such as waffle slab with slab edge insulation, the pods do not add much to the thermal performance as the concrete ribs bypass this layer. They would also likely fail the mandatory minimum fRsi requirement. For this reason, only fully insulated slabs are encouraged and assessed in this design guide.

11. The effectiveness of **ventilation systems** vary a lot in different climate zones. In warmer climates like Auckland, the percentage of heat loss through ventilation and air infiltration is significantly less than in colder climate zones like Christchurch. Without MVHR, the ventilation heat loss in Christchurch can be as much as all external walls combined.

12. Airtightness is for energy and moisture control. Where airtightness is assumed to be below 5 air changes per hour in ECCHO, it needs to be proven with a pressure test.

13. Thermal bridges normally have a small impact on performance as long as they meet the mandatory minimum fRsi requirement. Our main concern here is avoiding condensation and mould risk.

14. Heating and hot water systems have no impact on heating demand but have significant impact on total electricity demand. The project may meet the heating demand target but fail the total electricity demand unless extensive use of heat pumps is specified.

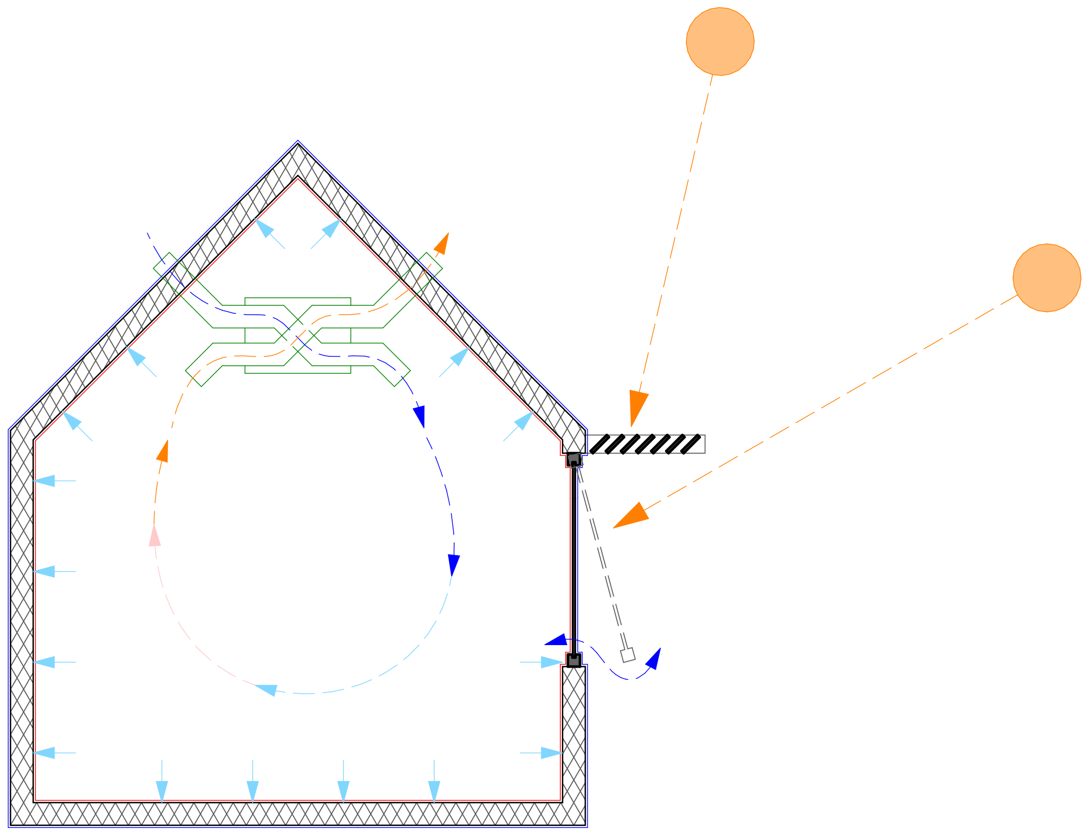
15. Natural ventilation is an effective way to reduce summer overheating. However, a conservative assumption must be used, therefore it is not sufficient to provide natural ventilation. Natural ventilation relies on the weather and occupant behaviour, neither of which can be guaranteed, and during winter contributes to significant heat loss.

16. Temporary and/or fixed shading devices are required to meet the overheating target in most cases. The solution is often very project specific, ranging from internal window treatment, external blind / shutter, custom privacy / shading screen, window surround, to louvre / pergola systems. The effect must be assessed in ECCHO with the best possible parameters. Sometimes, it could require a reasonable guesstimate based on the designer's judgement.

Mandatory minimums

Each Homestar star band has a set of mandatory minimums that must be met. These dictate the performance levels we are aiming to achieve in each climate zone with each typology.

The following table shows the minimums applicable to all climate zones within each star band, and those that differentiate based on climate zone:



A building must be considered holistically, as each decision will impact other areas of the building design and performance, and they all work together, as a system.

Mandatory Minimums

		Homestar 6			Homestar 8		
	Credit	**Auckland 1**	**Wellington 3**	**Christchurch 5**	**Auckland 1**	**Wellington 3**	**Christchurch 5**
	HC1	The main living area must have an adequately sized fixed heating system.					
	HC3	All doors between conditioned space and garage must be fully sealed.					
	HC3	All combustion appliances must be room sealed.					
	HC4	Windows must be thermally broken.					
	HC4	All junctions between external walls, floors and roofs must be demonstrated to meet the minimum fRsi factors for the respective climate zone.					
	HC4	Ground vapour barrier must be installed to the ground below all suspended floors.					
Maximum water consumption	**EF3**	145l/p			120l/p		
Maximum delivered energy (excluding appliances)	**EF4**	52	65	78	31	35	40
Winter Comfort - space heating demand	**HC1**	40	60	80	20	24	28
Onsite greenhouse gas emmisions	**EF4**	4kg.CO2-e/m2			2kg.CO2-e/m2		
Overheating	**HC2**	7% of the year over 25°C			5% of the year over 25°C		
Ventilation	**HC3**	Continuous extract			Commissioned continuous extract ventilation meeting the requirements OR balanced mechanical ventilation must be installed as a minimum.		
Pressure test	**HC4**	N/A			Maximum pressure test result at 50 Pa is 3 m3/m2/hr.		
Air & Vapour barriers	**HC4**	N/A			Identified		
Carbon	**EN2**	Projects must carry out a full lifecycle assessment, modules A-D of EN 15978.			Projects must carry out a full lifecycle assessment, modules A-D of EN 15978.		

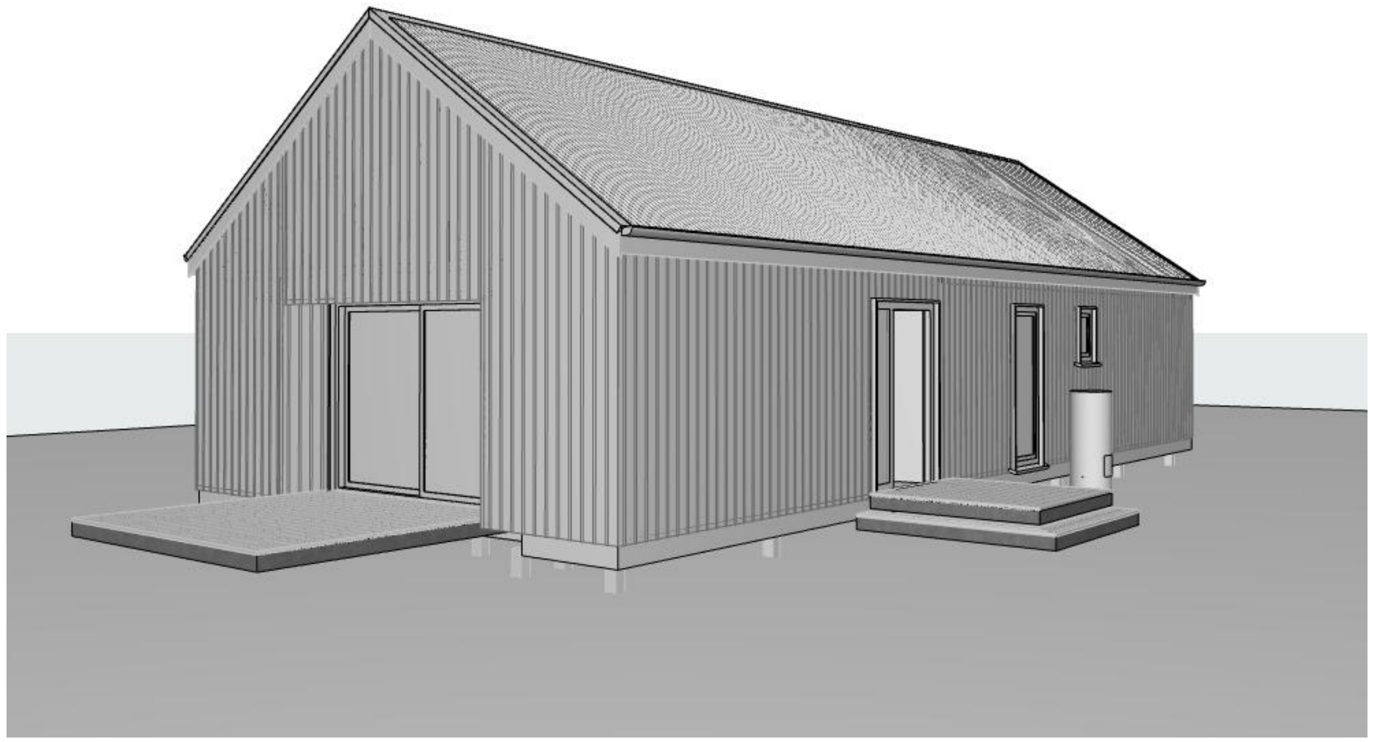
Case study 1 - Single storey standalone house - low glazing

Conditioned floor area:	**93m2**
Thermal mass type:	**Timber floor on piles**
Window to wall ratio:	**16%**
Form factor:	**3.9**

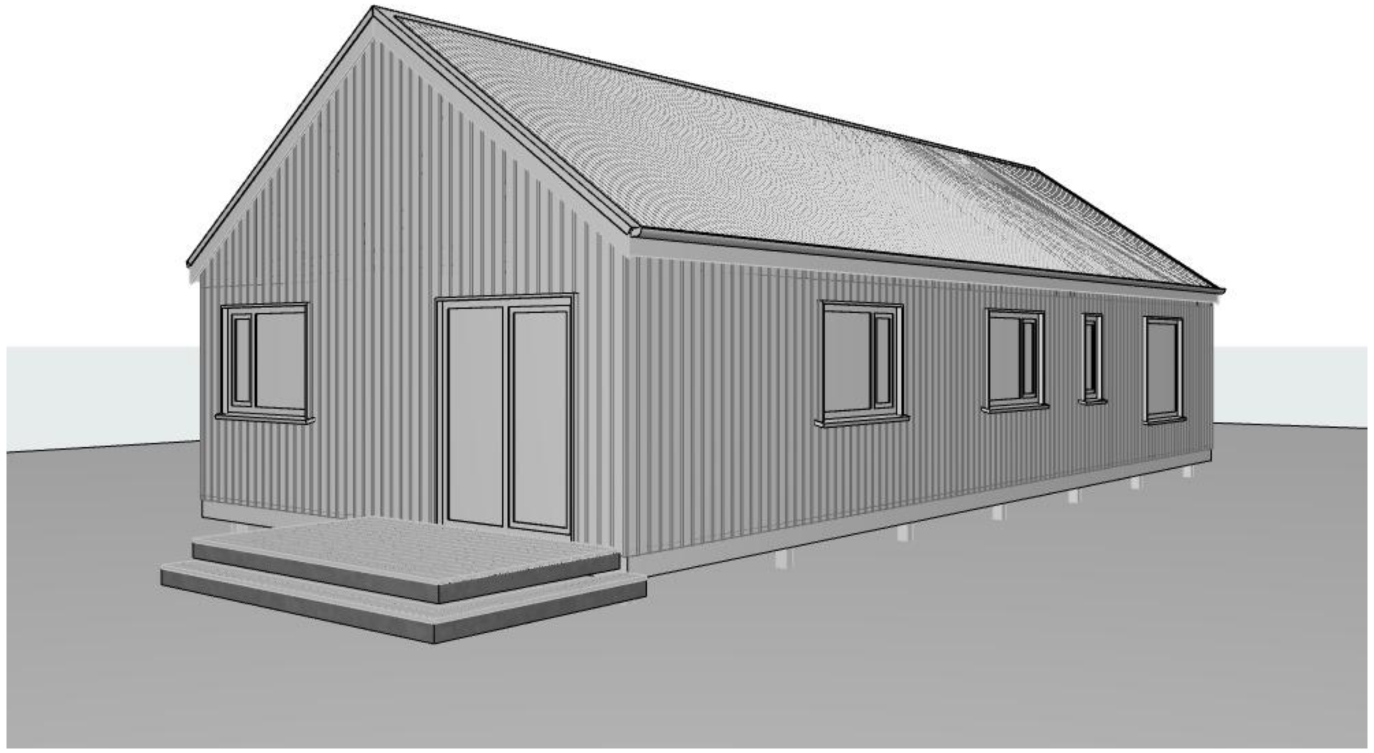
Case study 1 is a single storey, stand alone home with three bedrooms, a bathroom and a WC. It is on a suspended timber floor and has a combination of a flat and raking ceiling. The design has a simple form and compact footprint which makes achieving higher performance levels more straight forward. The more complex the form, the more external heat loss area, the harder it would be to achieve performance.

Performance considerations for case study 1

- Light timber frame construction generally means the entire house is easy to insulate and is easy to add more insulation to both floor and roof when required.
- Light timber frame construction has little to no thermal bridging to be concerned about when there is no steel or concrete involved. In most cases, this automatically fulfils the fRsi thermal bridge and mould assessment requirement.
- Low glazing to wall ratio makes the overheating target easy to achieve, which avoids additional effort and cost to design and build specific shading devices.
- Low glazing to wall ratio can limit heat loss but it is not necessarily positive for the overall energy balance as it can limit solar gain, too. Careful design and window placement are still required to achieve the right balance.

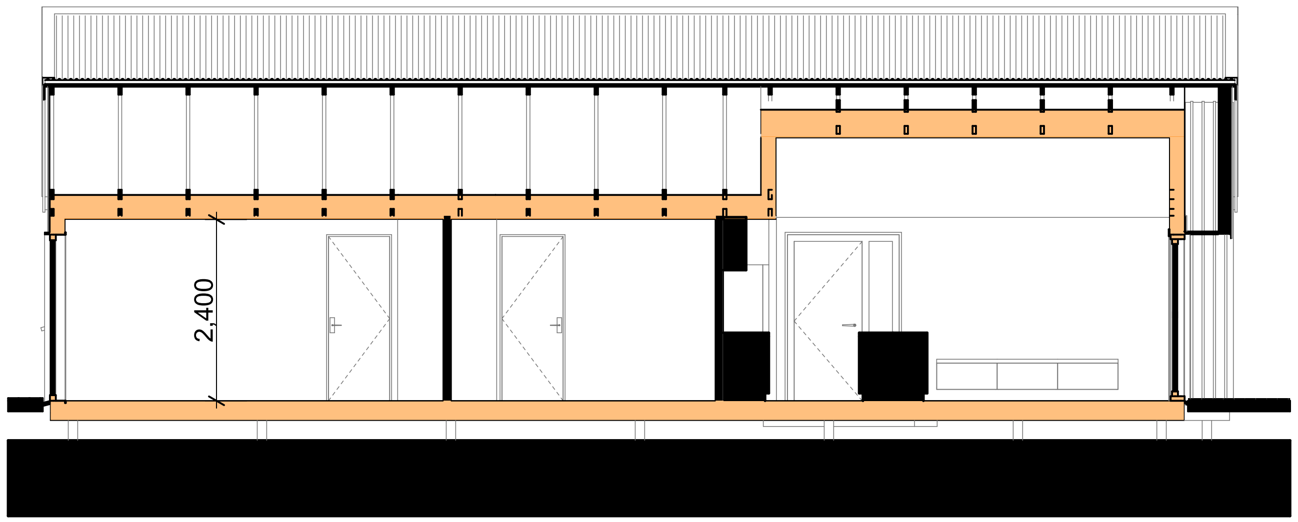


EXTERIOR 1

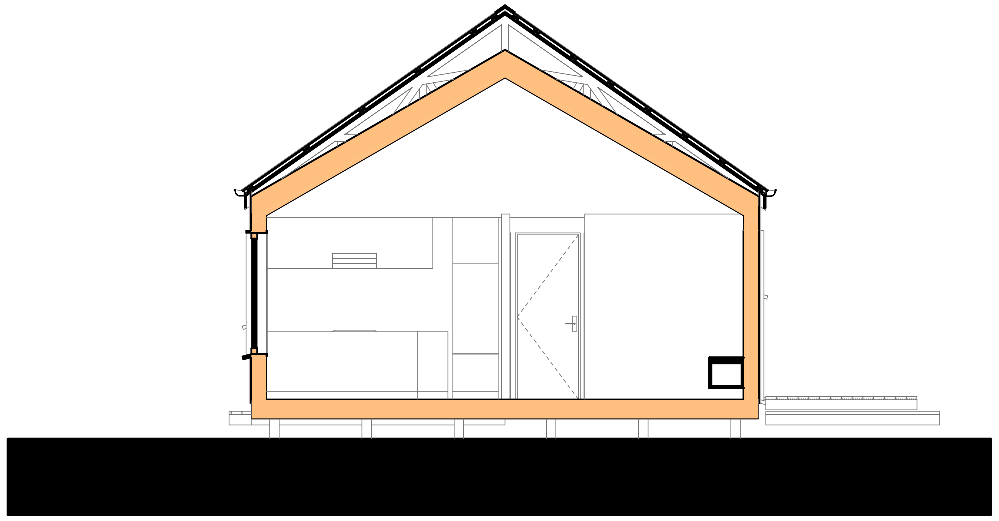


EXTERIOR 2

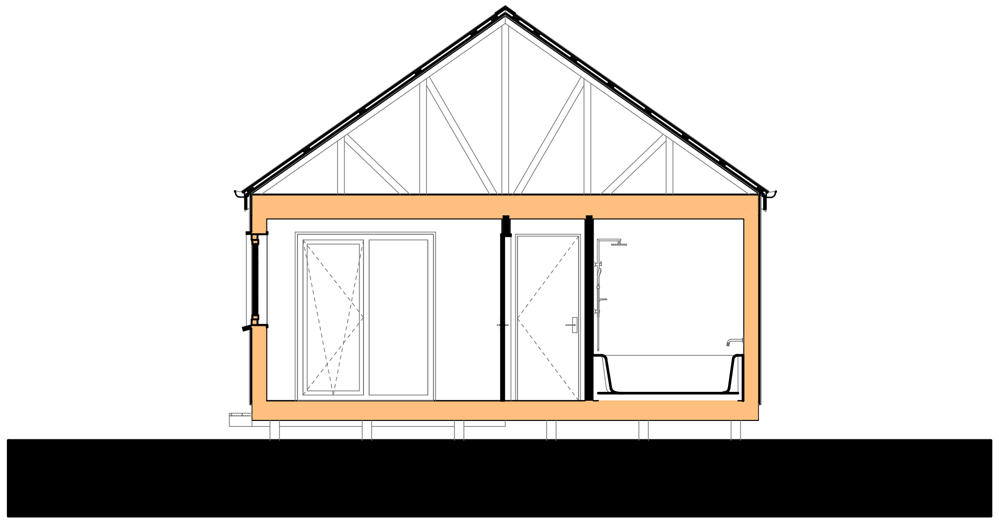
Thermal Envelope



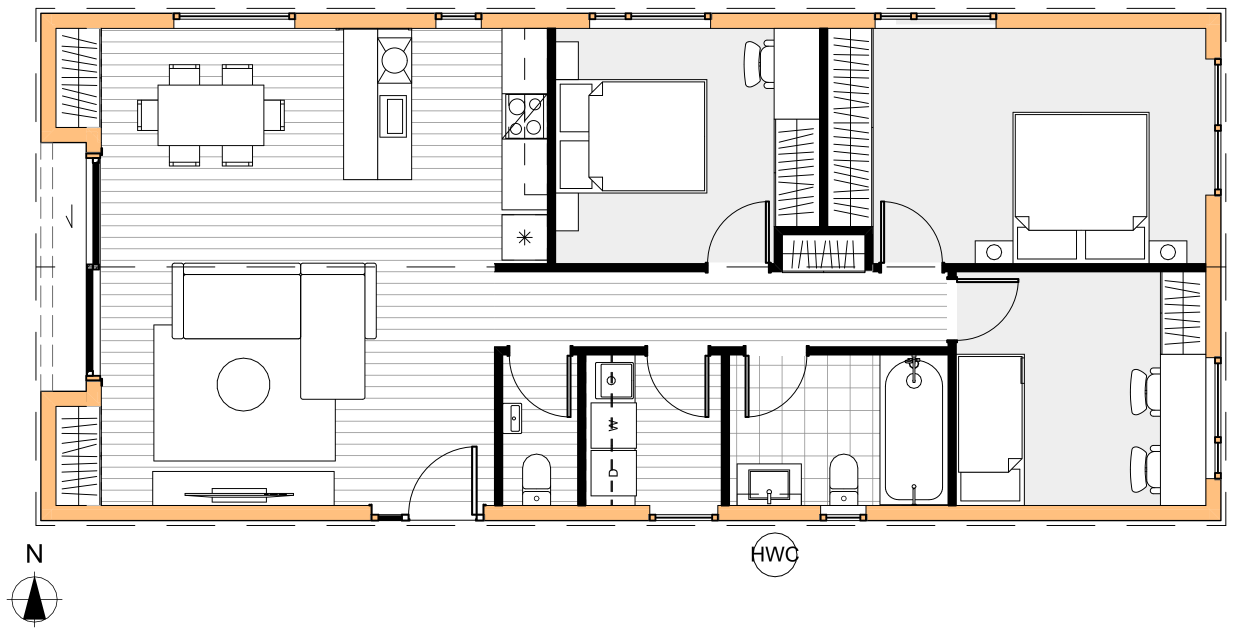
LONG SECTION



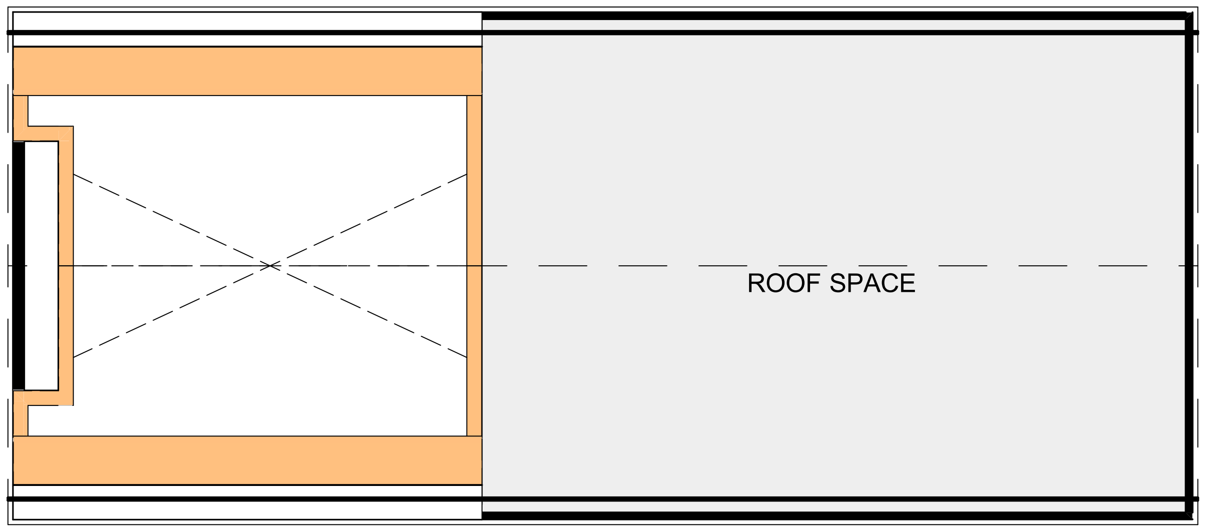
SHORT SECTION 01



SHORT SECTION 02

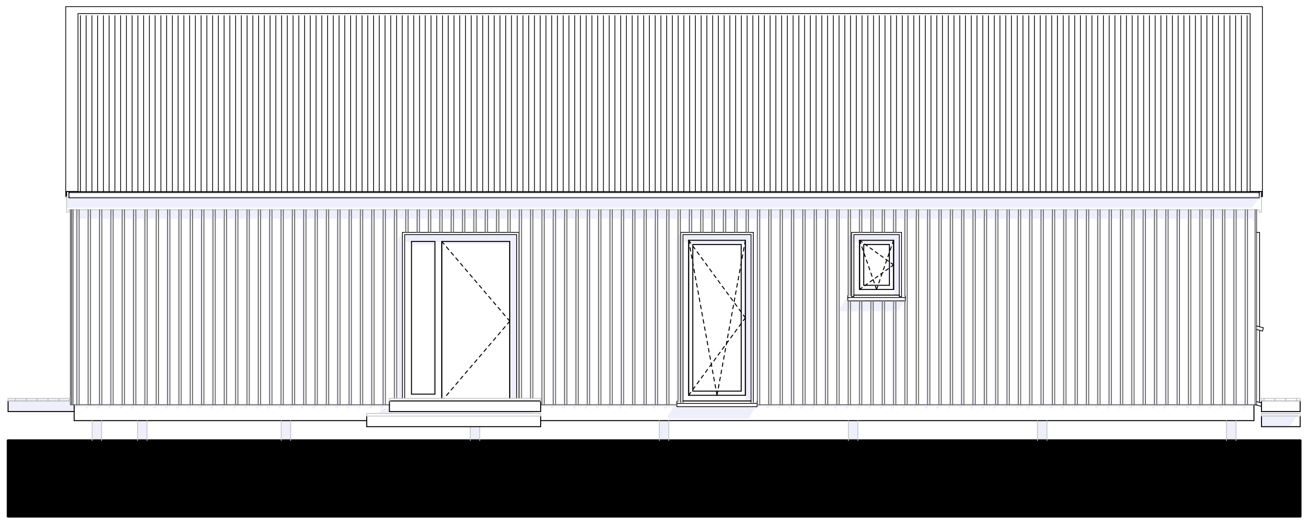


GROUND FLOOR

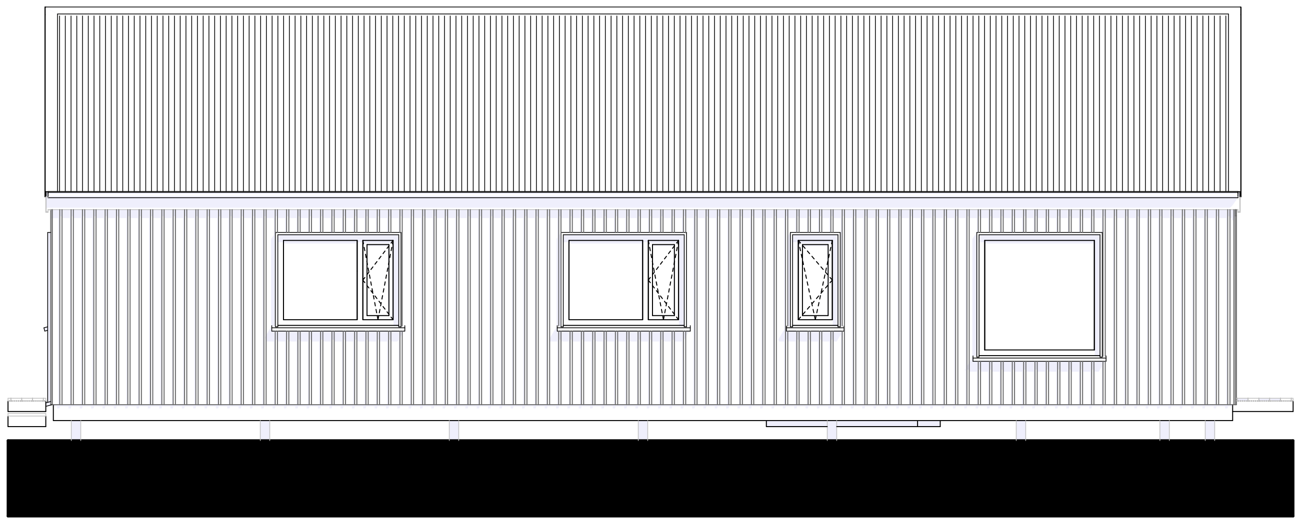


ROOF SPACE

EAST ELEVATION PROPOSED



SOUTH ELEVATION PROPOSED



NORTH ELEVATION PROPOSED

WEST ELEVATION PROPOSED

Case study 1 - Specification

The below table shows the different specification upgrades needed from Building Code minimum, ordered by Homestar level and climate severity. This demonstrates how some specifications are suitable for a range of climates.

For thermal bridges the table refers to the High Performance Construction Details Handbook (HPCDH) which is explained in greater detail in the Moisture Control chapter.

<table>
<tr><th></th><th>AKL HS6</th><th>WLG HS6</th><th>CHCH HS6</th><th>AKL HS8</th><th>WLG HS8</th><th>CHCH HS8</th></tr>
<tr><td>Floor</td><td colspan="4">FLOOR: Suspended Floor with 190 insulation</td><td colspan="2">FLOOR: Suspended Floor with 240 insulation</td></tr>
<tr><td>Wall</td><td>WALL: 90 framing (30% timber content)</td><td colspan="2">WALL: 140 framing (30% timber content)</td><td>WALL: 90 framing + 45 service cavity with airtight membrane (30% timber content)</td><td colspan="2">WALL: 140 framing + 45 service cavity with airtight membrane optimised (15% timber content)</td></tr>
<tr><td>Roof</td><td colspan="3">ROOF: R6.6 Rafter/Truss roof</td><td colspan="3">ROOF: R7.7 Rafter/Truss roof with insulated ceiling cavity</td></tr>
<tr><td>Thermal Bridges</td><td colspan="4">HPCD 45 - External Wall to suspended timber Floor Slab - 90mm stud wall current practice</td><td colspan="2">HPCD 46 - External Wall to suspended timber Floor Slab - 140/45 stud wall fully insulated timber floor
HPCD 57 - Truss Ceiling Roof Eaves - Truss roof raised heel to maintain insulation thickness
HPCD 8 - External Wall - External corner 140/45 stud wall no extra timber</td></tr>
<tr><td>Window frame</td><td colspan="3">ECCHO Aluminium thermally broken</td><td colspan="2">ECCHO generic PVC frame (recessed)</td><td>Optimal PVC frame (supplier specific data, recessed)</td></tr>
<tr><td>Glass</td><td colspan="3">ECCHO Double Low-e Arg Best (Ug=1.30)</td><td>ECCHO Double Low-e Arg Exceptional (Ug=1.10)</td><td>ECCHO Double Low-e Arg Best (Ug=1.30)</td><td>Triple Low-e Arg Exceptional (supplier specific data, Ug=0.60, g=0.49)</td></tr>
<tr><td>Door panel</td><td colspan="4">ECCHO Standard door</td><td colspan="2">Insulated front door panel (supplier specific data)</td></tr>
<tr><td>Shading objects</td><td colspan="6">Only internal blinds on all windows except front door</td></tr>
<tr><td>Ventilation</td><td colspan="4">Continuous extract 0% heat recovery efficiency</td><td colspan="2">MVHR 82% heat recovery efficiency</td></tr>
<tr><td>Airtightness (ACH n50)</td><td colspan="3">5</td><td>3.0 with airtight membrane</td><td>2.0 with airtight membrane</td><td>1.5 with airtight membrane</td></tr>
<tr><td>Heater</td><td colspan="6">50% heat pump (R32 refrigerant)
50% electric panel heater</td></tr>
<tr><td>Hot water</td><td colspan="3">100% electric HWC</td><td colspan="3">100% heat pump (R744/CO2 refrigerant)</td></tr>
</table>

Case study 1 - Results

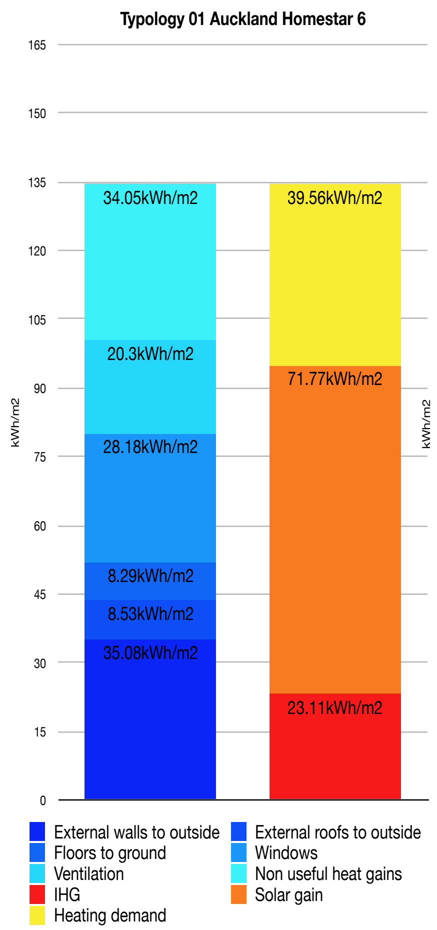
These are the results of the design work flow and what you will end up with after going though the modelling and refinement process.

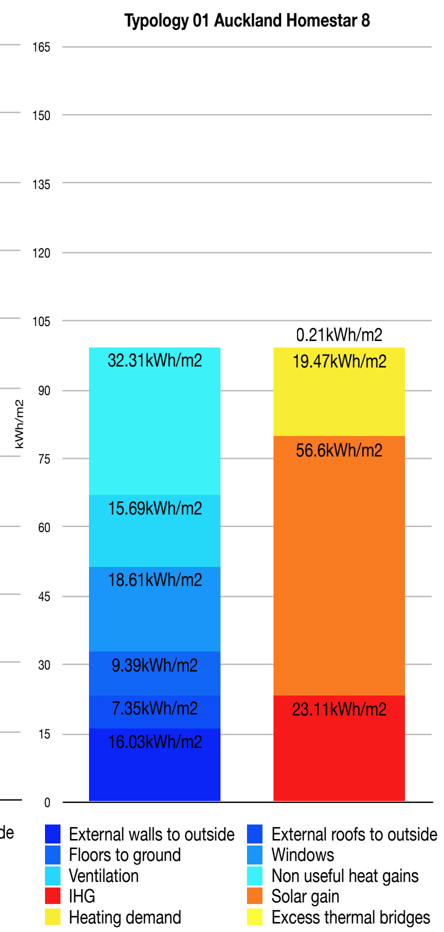
As can be seen below, the balance of the heat losses in all climates is relatively even across all of the building elements. For Homestar 6 the total energy use increases as the climates become more severe. However the total energy use of the Homestar 8 homes remains relatively similar, demonstrating the higher level of performance no matter what climate.

Auckland

Homestar 6
- Annual space heating demand: 39.6
- Annual electricity demand: 43.5
- Overheating without mechanical cooling: 5.3%

Homestar 8
- Annual space heating demand: 19.5
- Annual electricity demand: 28.8
- Overheating without mechanical cooling: 3.4%

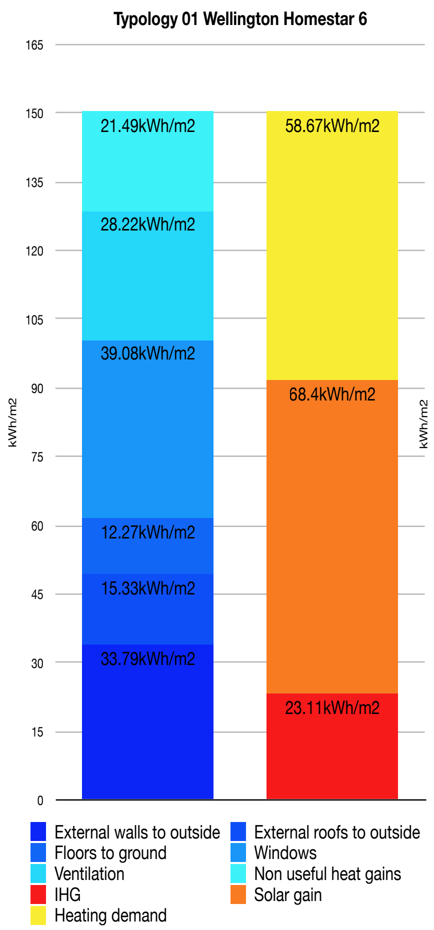


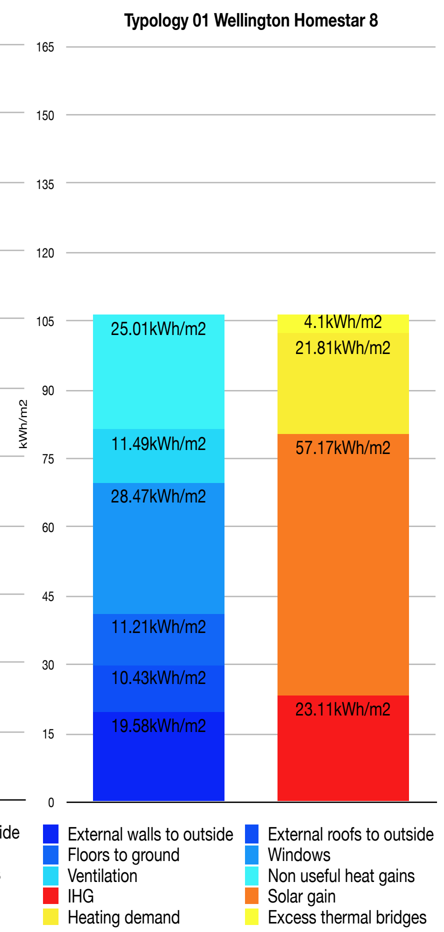


Wellington

Homestar 6
- Annual space heating demand: 58.7
- Annual electricity demand: 58.1
- Overheating without mechanical cooling: 1.6%

Homestar 8
- Annual space heating demand: 21.8
- Annual electricity demand: 31.9
- Overheating without mechanical cooling: 1.1%

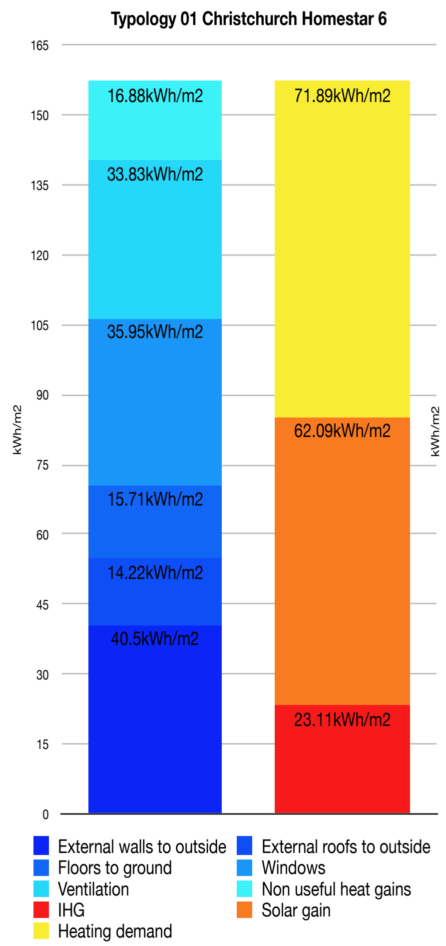


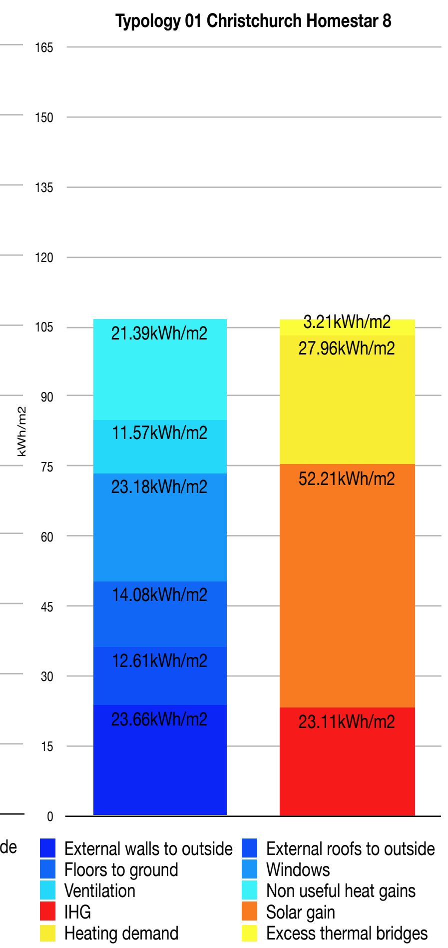


Christchurch

Homestar 6
- Annual space heating demand: 71.9
- Annual electricity demand: 68.2
- Overheating without mechanical cooling: 1.1%

Homestar 8
- Annual space heating demand: 28
- Annual electricity demand: 36.8
- Overheating without mechanical cooling: 0.9%





Case study 1 - Costing

The following tables show the different specification upgrades needed from Building Code minimum, to achieve Homestar 6 and Homestar 8 in the three different climate zones, and the related costs for each element.

Case Study 01 - Auckland

	Auckland					
	Building Code Minimum		**Homestar 6**		**Homestar 8**	
Building total cost per m2	$3,783		$3,818		$3,994	
Increase from Building Code minimum	0.0%		0.1%		6.5%	
Floor	Suspended Floor with 140 insulation	$25,235	Suspended Floor with 190 insulation	$515	Suspended Floor with 190 insulation	$515
Walls	90mm framing with R2.8 insulation	$12,566	No change	-	+$ for 45mm insulated services cavity	$4,223
Roof	R7.0 insulation between trusses	$6,180	No change	-	+$ for increase to R7.7 insulation and insulated services cavity	$2,060
Window frames	Thermally broken aluminium frame	$14,111	+$ for trickle vents	$2,000	+$ for standard UPVC frames & recessed flashings	$4,233
Window glass	Low e argon filled, double glazing unit. Ug=1.3	$14,111	No change	-	+ cost for double low-e argon exceptional	$2,060
Door panel	Standard front door panel	$1,493.50	No change	-	No change	-
Ventilation	Extractor fan in each bathroom and laundry	$660	+$ for continuous extract	$1,040	+$ for continuous extract	$1,040
Airtightness	No airtight construction	-	No change	-	+$ for airtightness membrane to walls and roof	$6,180
Heater	1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$4,120	No change	-	No change	-
Hot water	Electric hot water cylinder	$4,000	No change	-	+$ for heat pump hot water cylinder	$1,500
Additional cost	**-**		**$3,555**		**$21,811**	

Case Study 01 - Wellington

	Wellington					
	Building Code Minimum		Homestar 6		Homestar 8	
Building total cost per m2	$3,577		$3,651		$3,897	
Increase from Building Code minimum	0.0%		2.0%		8.4%	
Floor	Suspended Floor with 140 insulation	$23,844	Suspended Floor with 190 insulation	$490	Suspended Floor with 240 insulation	$600
Walls	$ 90mm framing with R2.8 insulation	$11,875.90	+$ for 140mm wall framing & 140 insulation	$4,120	+$ for 140mm wall framing & 140 insulation. +45mm insulated services cavity	$6,180
Roof	$ R7.0 insulation between trusses	$5,840	No change	-	+$ for increase to R7.7 insulation and insulated services cavity	$2,060
Window frames	$ Thermally broken aluminium frame	$13,390	+$ for trickle vents	$2,000	+$ for standard UPVC frames & recessed flashings	$4017
Window glass	Low e argon filled, double glazing unit. Ug=1.3	$13,390	No change	-	No change	
Door panel	$ Standard front door panel	$1,410	No change	-	+$ for better door panel	$460
Ventilation	$ Extractor fan in each bathroom and laundry	$630	+$ for continuous extract	$1,040	+$ for MVHR	$12,000
Airtightness	$ No airtight construction	-	No change	-	+$ for airtightness membrane to walls and roof	$6,180
Heater	$ 1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$3,890	No change	-	No change	-
Hot water	$ Electric hot water cylinder	$3,800	No change	-	+$ for heat pump hot water cylinder	$1,500
Additional cost	**-**		**$7,650**		**$32,997**	

Case Study 01 - Christchurch

	Christchurch					
	Building Code Minimum		Homestar 6		Homestar 8	
Building total cost per m2	$3,715		$3,835		$4,097	
Increase from Building Code minimum	0.0%		3.1%		10.1%	
Floor	Suspended Floor with 140 insulation	$24,352	Suspended Floor with 190 insulation	$515	Suspended Floor with 240 insulation	$824
Walls	$ 90mm framing with R2.8 insulation	$12,360	+$ for 140mm wall framing & 140 insulation	$4,120	+$ for 140mm wall framing & 140 insulation. +45mm insulated services cavity	$6,180
Roof	$ R7.0 insulation between trusses	$6,077	No change	-	+$ for increase to R7.7 insulation and insulated services cavity	$2,060
Window frames	$ Thermally broken aluminium frame	$13,900	+$ for standard UPVC frames and trickle vents	$4170	+$ for high performance UPVC frames	$7,500
Window glass	$ Metro low-e Xtreme or Viridian PerformaTech Low-e, argon filled, double glazing unit	$13,900	-$ Metro low-e Xcel or Viridian Lightbridge Low-e, argon filled, double glazing unit	$1,030	+ cost for triple low-e argon exceptional	$2,600
Door panel	$ Standard front door panel	$1,470	No change	-	+$ for better door panel	$515
Ventilation	$ Extractor fan in each bathroom and laundry	$650	+$ for continuous extract	$1,040	+$ for MVHR	$12,000
Airtightness	$ No airtight construction		No change	-	+$ for airtightness membrane to walls and roof	$6,180
Heater	$ 1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$4,120	No change	-	No change	-
Hot water	$ Electric hot water cylinder	$3,950	+$ for heat pump hot water cylinder	$1,500	+$ for heat pump hot water cylinder	$1,500
Additional cost	**-**		**$12,375**		**$39,359**	

Case study 2 - Single storey standalone house - high glazing

Conditioned floor area: **93m^2**

Thermal mass type: **Concrete slab, single level timber**

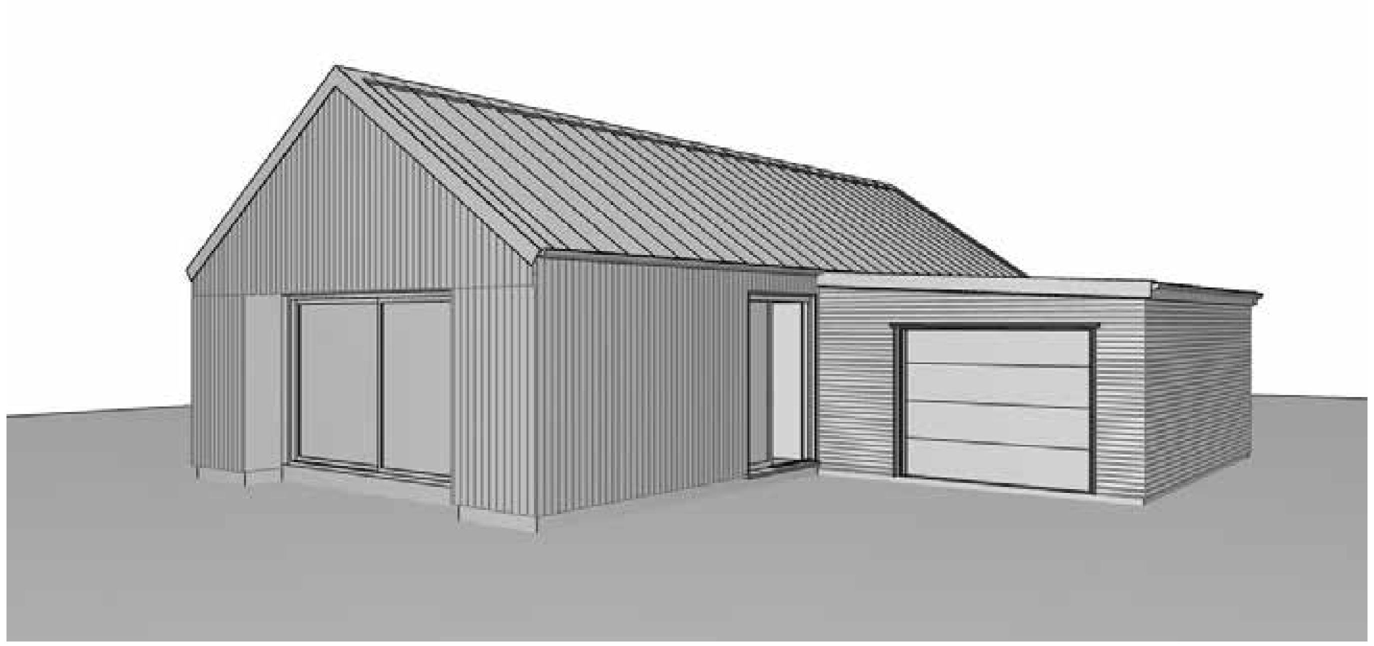
Window to wall ratio: **28%**

Form factor: **4.0**

Case study 2 is the same single storey, standalone home with three bedrooms, a bathroom and a WC, as case study 1, however it is on a concrete slab, has an attached garage, and has a higher glazing ratio. These changes will make it harder to achieve higher levels of performance due to the slab edge and garage slab connection thermal bridges, and while the higher levels of glazing will allow more 'free' heat, they will also contribute to overheating levels.

Performance considerations for case study 2

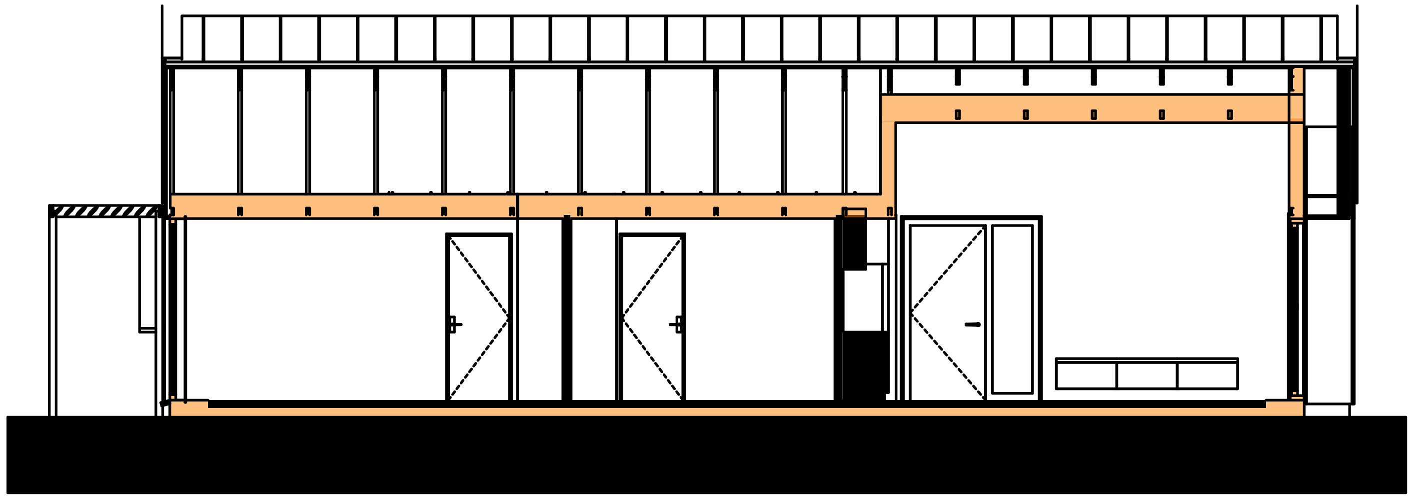
- A concrete slab with light timber frame on top poses challenges for insulation around and underneath the floor to enable continuous insulation of the thermal envelope. Proprietary or SED (specific engineering design) fully insulated slab system must be used.
- A concrete slab with light timber frame on top means the only common concern for thermal bridging is limited to the perimeter and the junction between the house and the garage. A fully insulated slab system with 30-50mm XPS thermal break would generally meet the fRsi requirement in both situations.
- High glazing to wall ratio makes the overheating targets hard to achieve, which would likely require additional effort and cost to design and build specific shading devices.
- High glazing to wall ratios normally come with higher heat loss but also higher heat gain too. Careful design and window placement is always required to achieve the right balance.
- Thermal mass from a concrete slab has a small positive effect on both heating demand and overheating.



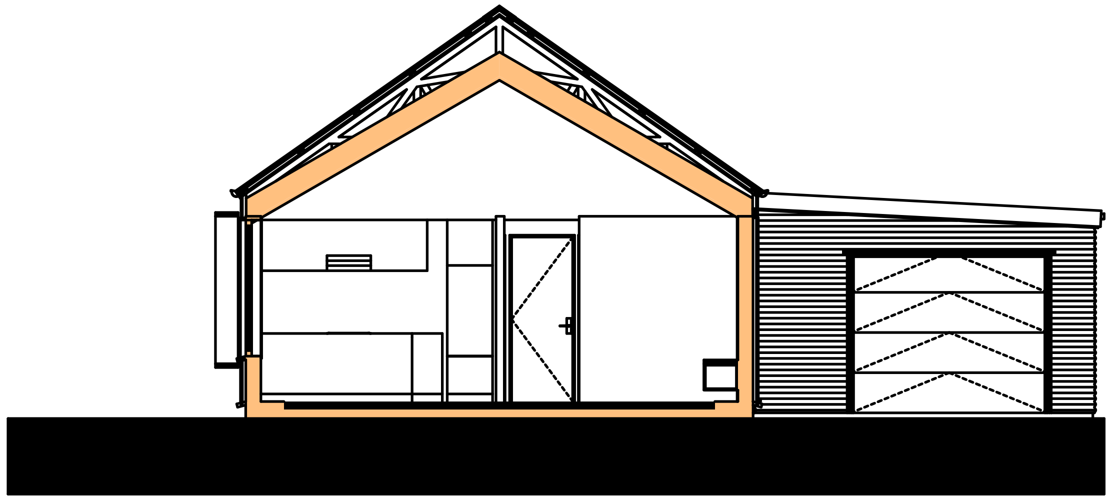
EXTERIOR 1

EXTERIOR 2

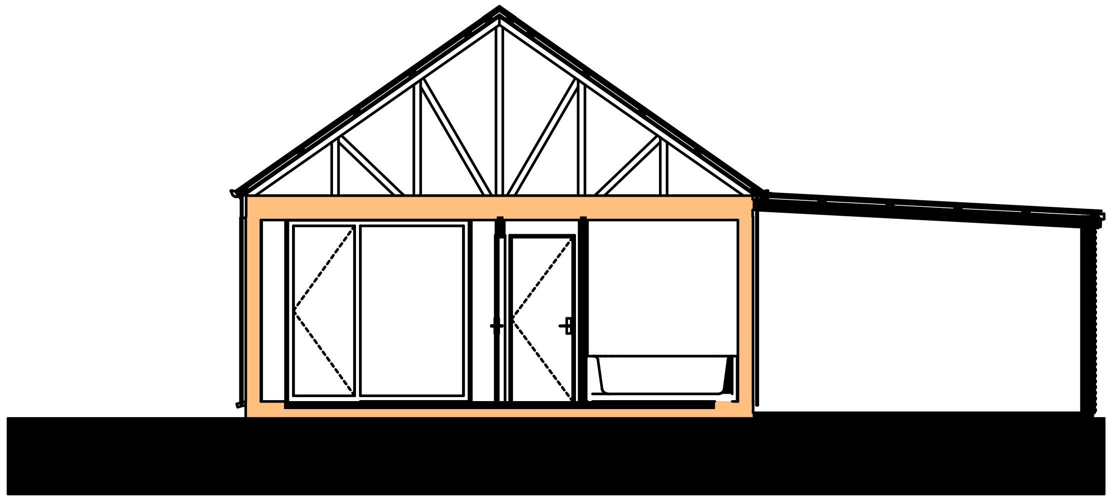
Thermal Envelope



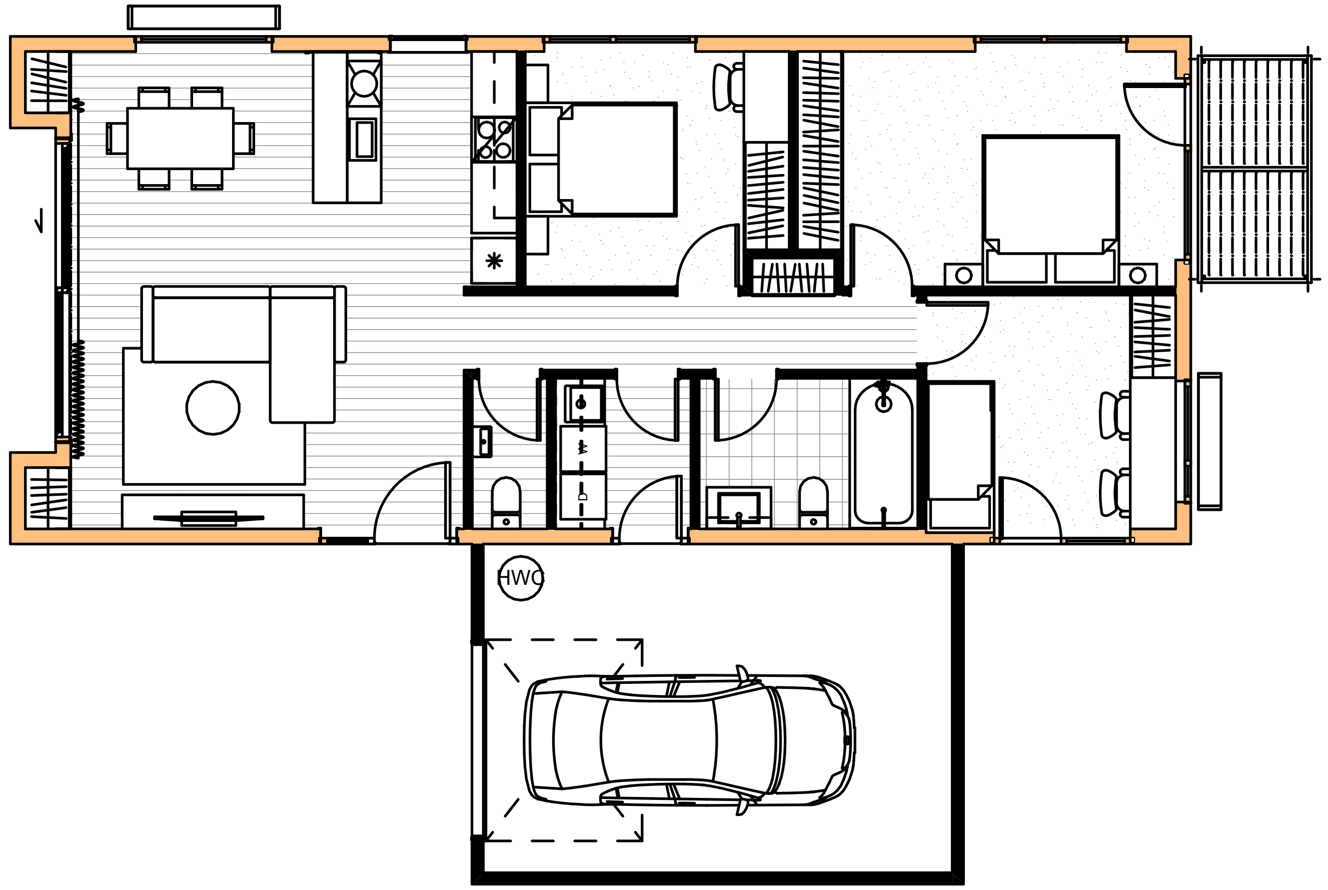
SECTION C



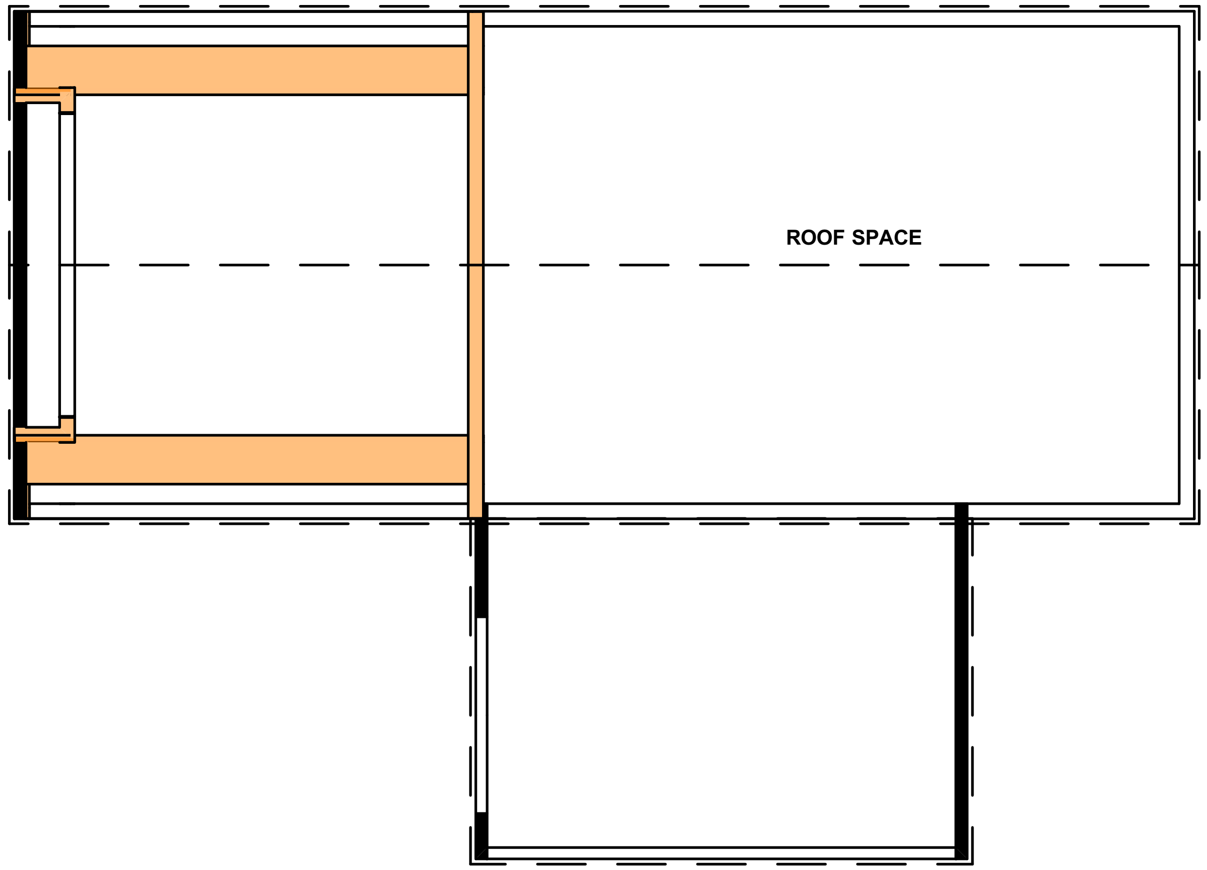
SECTION A



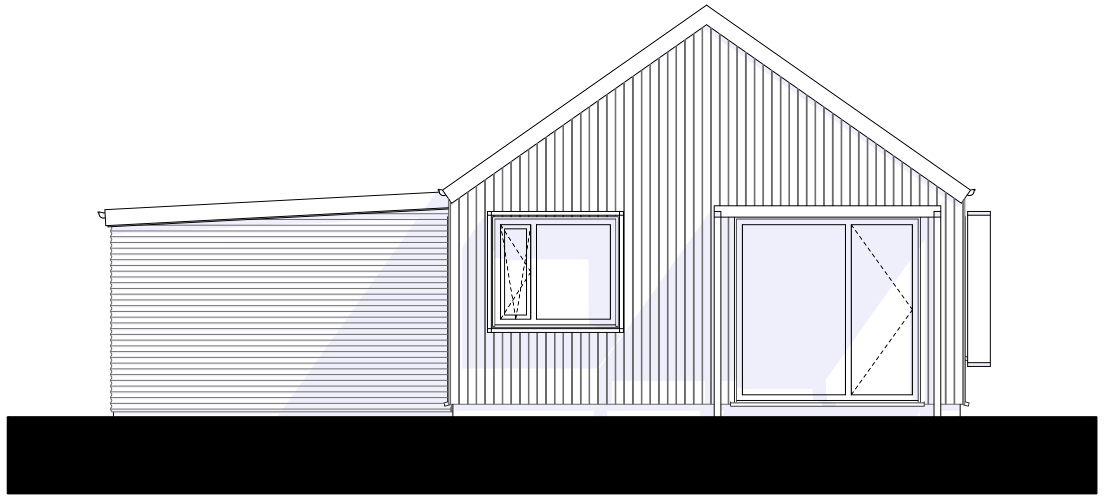
SECTION B



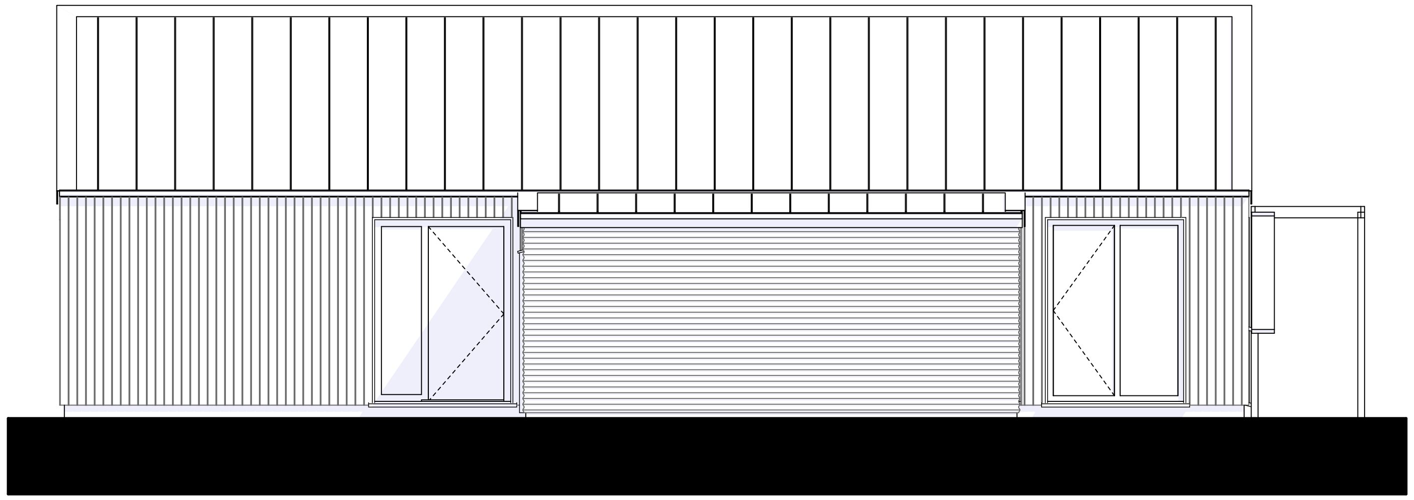
GROUND FLOOR



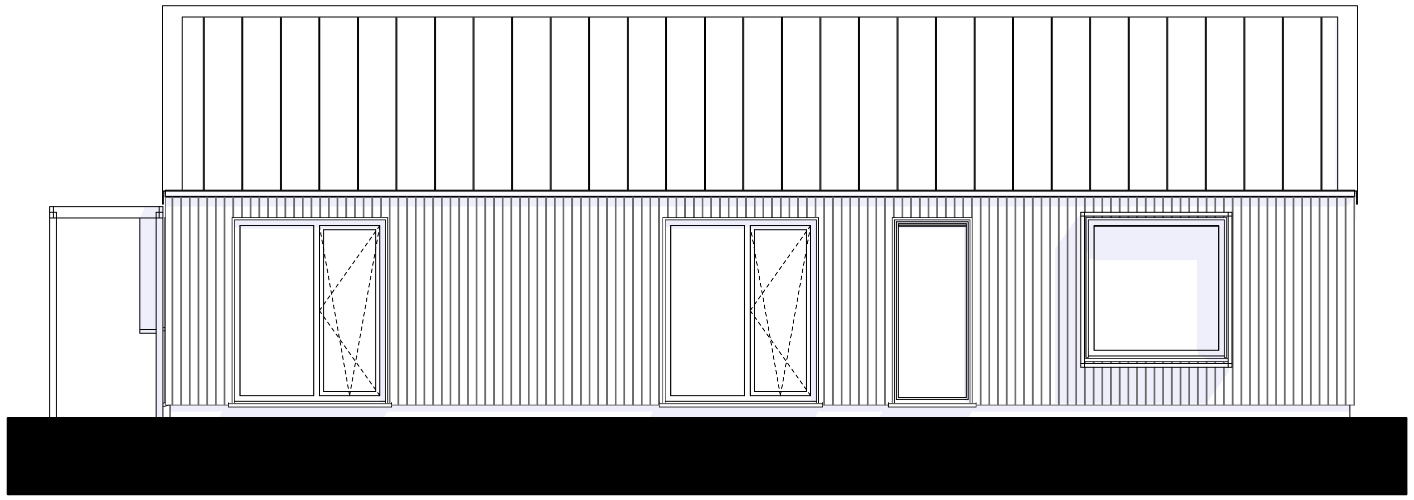
ROOF SPACE



EAST ELEVATION PROPOSED



SOUTH ELEVATION PROPOSED



NORTH ELEVATION PROPOSED

WEST ELEVATION PROPOSED

Case study 2 - Specification

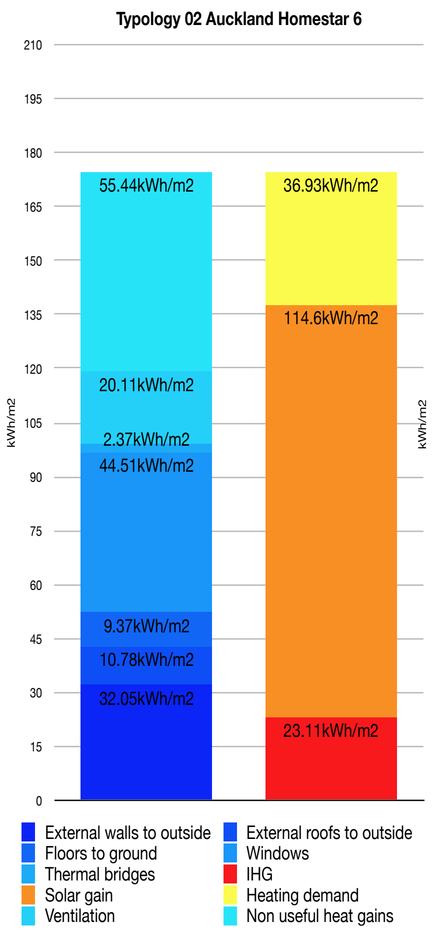
<table>
<tr><th></th><th>AKL HS6</th><th>WLG HS6</th><th>CHCH HS6</th><th>AKL HS8</th><th>WLG HS8</th><th>CHCH HS8</th></tr>
<tr><td>Floor</td><td colspan="4">FLOOR: Waffle Slab 220 solid pods with ribs and 50mm EPS under</td><td colspan="2">FLOOR: Waffle Slab 300 solid pods with ribs and 50mm EPS under</td></tr>
<tr><td>Wall</td><td>WALL: 90 framing (30% timber content)</td><td colspan="2">WALL: 140 framing (30% timber content)</td><td>WALL: 90 framing + 45 service cavity with airtight membrane (30% timber content)</td><td colspan="2">WALL: 140 framing + 45 service cavity with airtight membrane optimised (15% timber content)</td></tr>
<tr><td>Roof</td><td colspan="3">ROOF: R5.2 Rafter/Truss roof</td><td>ROOF: 6.6 Rafter/Truss roof</td><td colspan="2">ROOF: R7.7 Rafter/Truss roof with insulated ceiling cavity</td></tr>
<tr><td>Thermal Bridges</td><td>ECCHO fully insulated slab 300 90mm timber clad</td><td colspan="2">ECCHO fully insulated slab 300 140mm timber clad</td><td colspan="3">HPCD 39: EWFS – 140/45 stud wall insulated waffle pod slab edge insulation and full insulation under ribs</td></tr>
<tr><td>Window frame</td><td colspan="3">ECCHO Aluminium thermally broken</td><td colspan="2">ECCHO generic PVC frame (recessed)</td><td>Optimal PVC frame (supplier specific data, recessed)</td></tr>
<tr><td>Glass</td><td colspan="3">ECCHO Double Low-e Arg Best (Ug=1.30)</td><td>ECCHO Double Low-e Arg Exceptional (Ug=1.10)</td><td>ECCHO Double Low-e Arg Best (Ug=1.30)</td><td>Triple Low-e Arg Exceptional (supplier specific data, Ug=0.60, g=0.49)</td></tr>
<tr><td>Door panel</td><td colspan="4">ECCHO Standard door</td><td colspan="2">Insulated front door panel (supplier specific data)</td></tr>
<tr><td>Shading objects</td><td colspan="6">External blind for sliding door
Louvre/pergola on 1 window
Window surround on 2 windows
Internal blinds on all windows</td></tr>
<tr><td>Ventilation</td><td colspan="4">Continuous extract 0% heat recovery efficiency</td><td colspan="2">MVHR 82% heat recovery efficiency</td></tr>
<tr><td>Airtightness (ACH n50)</td><td colspan="3">5</td><td>3.0 with airtight membrane</td><td>2.0 with airtight membrane</td><td>1.5 with airtight membrane</td></tr>
<tr><td>Heater</td><td colspan="6">50% heat pump (R32 refrigerant)
50% electric panel heater</td></tr>
<tr><td>Hot water</td><td colspan="3">100% electric HWC</td><td colspan="3">100% heat pump (R744/CO2 refrigerant)</td></tr>
</table>

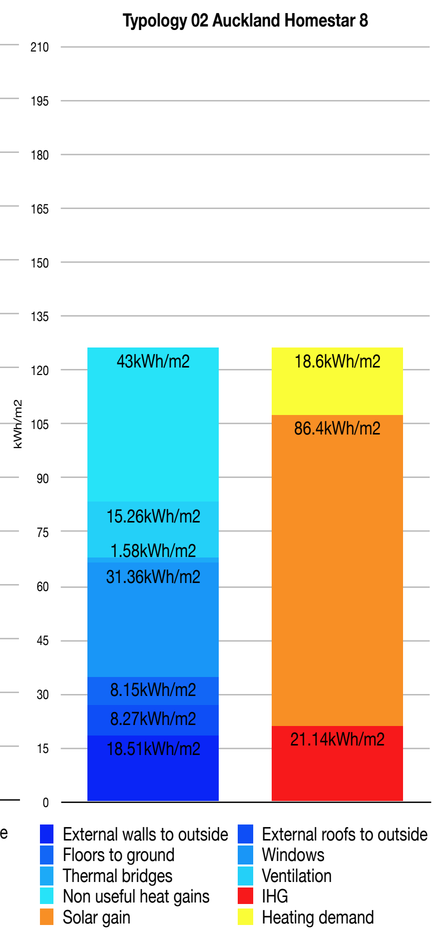
Case study 2 - Results

Auckland

Homestar 6
- Annual space heating demand: 36.9
- Annual electricity demand: 51
- Overheating without mechanical cooling: 4.5%

Homestar 8
- Annual space heating demand: 18.6
- Annual electricity demand: 30.1
- Overheating without mechanical cooling: 3.2%

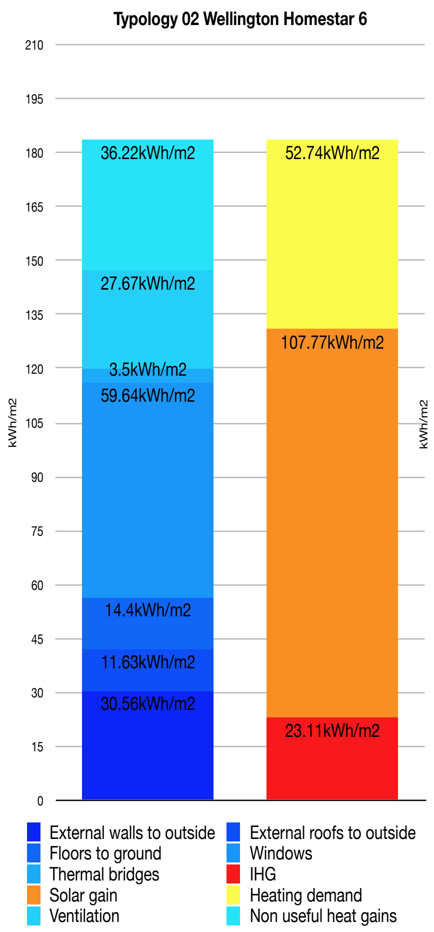


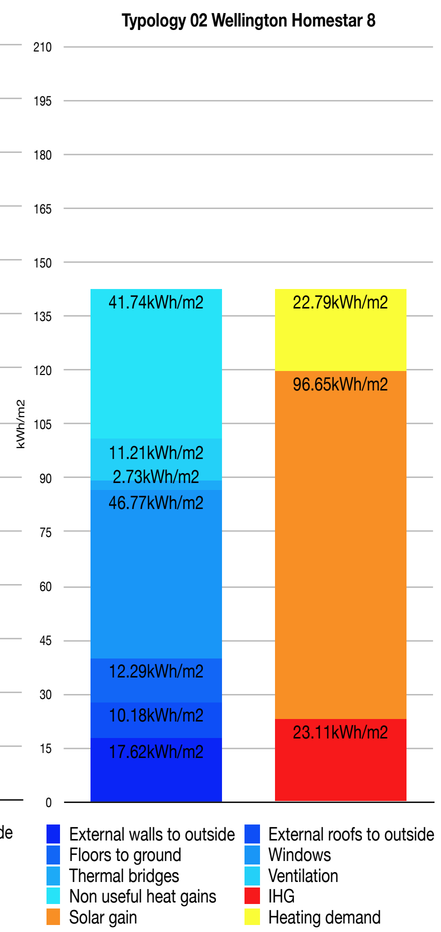


Wellington

Homestar 6
- Annual space heating demand: 52.7
- Annual electricity demand: 63.7
- Overheating without mechanical cooling: 1.0%

Homestar 8
- Annual space heating demand: 22.8
- Annual electricity demand: 34.6
- Overheating without mechanical cooling: 1.0%

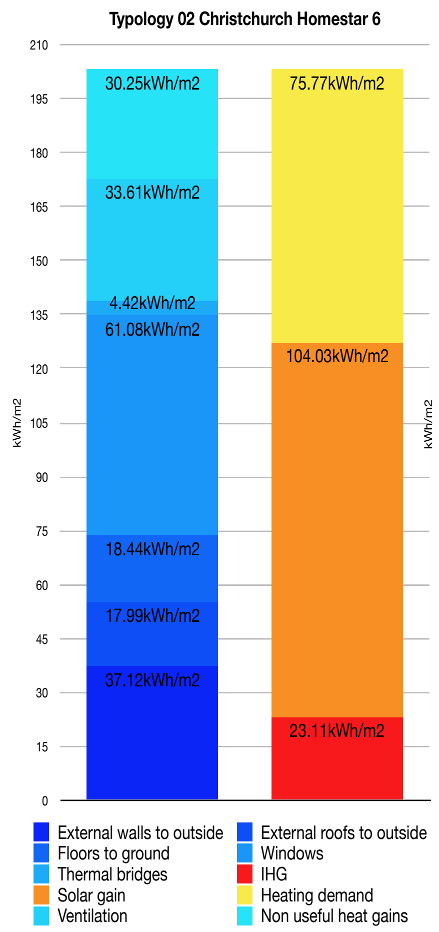


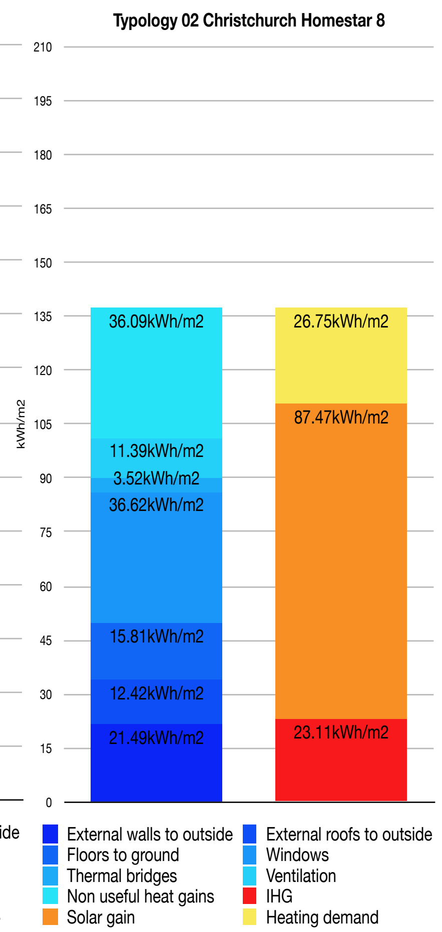


Christchurch

Homestar 6
- Annual space heating demand: 75.8
- Annual electricity demand: 70.9
- Overheating without mechanical cooling: 1.0%

Homestar 8
- Annual space heating demand: 26.7
- Annual electricity demand: 38,1
- Overheating without mechanical cooling: 0.8%





Case study 2 - Costing

The following tables show the different specification upgrades needed from Building Code minimum, to achieve Homestar 6 and Homestar 8 in the three different climate zones, and the related costs for each element.

Case Study 02 - Auckland

	Auckland					
	Building Code Minimum		**Homestar 6**		**Homestar 8**	
Building total cost per m2	$3,543.		$3,580.		$3,697.	
Increase from Building Code minimum	0.0%		1.0%		4.3%	
Floor	Raft slab with 220 pods and R1 edge insulation (30mm XPS with render over)	$40,000.	Raft slab with 220 pods and R1.3 50mm EPS under AND at perimeter	$1,500.	Raft slab with 220 pods and R1.3 50mm EPS under AND at perimeter	$1,500.
Walls	90mm framing with R2.8 insulation	$17,352.	No change	-	90 framing + 45 service cavity with airtight membrane (30% timber content)	$4,120.
Roof	R7.0 insulation between trusses	$7,847.	R5.2 Rafter/Truss roof	$400.	6.6 Rafter/Truss roof	$1,064.
Window frames	Thermally broken aluminium frame	$13,900.	+ tricke vent	$2,000.	ECCHO generic PVC frame (recessed)	$4,170.
Window glass	Argon filled, double glazing unit. Ug=1.3	$13,900.	No change	-	ECCHO Double Low-e Arg Exceptional (Ug=1.10)	$2,000.
Door panel	Standard front door panel	$1,470.	No change	-	No change	-
Ventilation	Extractor fan in each bathroom and laundry	$650.	Continuous extract 0% heat recovery efficiency	$1,040.	Continuous extract 0% heat recovery efficiency	$1,040.
Airtightness	No airtight construction	$.	5	$.	3 with airtight membrane	$5,080.
Heater	1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$4,120.	No change	-	No change	-
Hot water	Electric hot water cylinder	$3,950.	No change	-	100% heat pump (R744/CO2 refrigerant)	$1,500.
Additional cost	**-**		**$4,940.**		**$20,474.**	

Case Study 02 - Wellington						
	Wellington					
	Building Code Minimum		Homestar 6		Homestar 8	
Building total cost per m2	$3,348.		$3,425.		$3,643.	
Increase from Building Code minimum	0.0%		2.3%		8.8%	
Floor	Raft slab with 220 pods and R1 edge insulation (30mm XPS with render over)	$38,000.	Raft slab with 220 pods and R1.3 50mm EPS under AND at perimeter	$1,500.	Waffle Slab 300 solid pods with ribs and 50mm EPS under	$9,044.
Walls	90mm framing with R2.8 insulation	$16,484.	140 framing (30% timber content)	$5,320.	140 framing + 45 service cavity with airtight membrane optimised (15%)	$6,000.
Roof	R7.0 insulation between trusses	$7,455.	R5.2 Rafter/Truss roof	$400.	R7.7 Rafter/Truss roof with insulated ceiling cavity	$1,064.
Window frames	Thermally broken aluminium frame	$13,390.	+ tricke vent	$2,000.	ECCHO generic PVC frame (recessed)	$4,170.
Window glass	Argon filled, double glazing unit. Ug=1.3	$13,390.	No change	-	No change	-
Door panel	Standard front door panel	$1,410.	No change	-	Insulated front door panel (supplier specific data)	$500.
Ventilation	Extractor fan in each bathroom and laundry	$630.	Continuous extract 0% heat recovery efficiency	$1,040.	MVHR 82% heat recovery efficiency	$12,000.
Airtightness	No airtight construction	$.	5	$.	2.0 with airtight membrane	$5,080.
Heater	1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$3,890.	No change	-	No change	-
Hot water	Electric hot water cylinder	$3,800.	No change	-	100% heat pump (R744/CO2 refrigerant)	$1,500.
Additional cost	-		$10,260.		$39,358.	

Case Study 02 - Christchurch						
	Christchurch					
	Building Code Minimum		Homestar 6		Homestar 8	
Building total cost per m2	$3,479.		$3,558.		$3,794.	
Increase from Building Code minimum	0.0%		2.3%		9.1%	
Floor	Raft slab with 220 pods and R1 edge insulation (30mm XPS with render over)	$39,000.	Raft slab with 220 pods and R1.3 50mm EPS under AND at perimeter	$1,600.	Waffle Slab 300 solid pods with ribs and 50mm EPS under	$9,310.
Walls	90mm framing with R2.8 insulation	$17,000.	140 framing (30% timber content)	$5,500.	140 framing + 45 service cavity with airtight membrane optimised (15%)	$6,200.
Roof	R7.0 insulation between trusses	$7,700.	R5.2 Rafter/Truss roof	$400.	R7.7 Rafter/Truss roof with insulated ceiling cavity	$1,080.
Window frames	Thermally broken aluminium frame	$13,650.	+ tricke vent	$2,000.	Optimal PVC frame (supplier specific data, recessed)	$4,155.
Window glass	Argon filled, double glazing unit. Ug=1.1	$13,850.	No change	-	Triple Low-e Arg Exceptional (supplier specific data, Ug=0.60, g=0.49)	$2,080.
Door panel	Standard front door panel	$1,450.	No change	-	Insulated front door panel (supplier specific data)	$500.
Ventilation	Extractor fan in each bathroom and laundry	$640.	Continuous extract 0% heat recovery efficiency	$1,040.	MVHR 82% heat recovery efficiency	$12,000.
Airtightness	No airtight construction	$.	5	$.	1.5 with airtight membrane	$5,080.
Heater	1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$4,210.	No change	-	No change	-
Hot water	Electric hot water cylinder	$3,950.	No change	-	100% heat pump (R744/CO2 refrigerant)	$1,500.
Additional cost per m2	**-**		**$10,540.**		**$41,905.**	

Case study 3 - Multi-unit two storey terraced homes

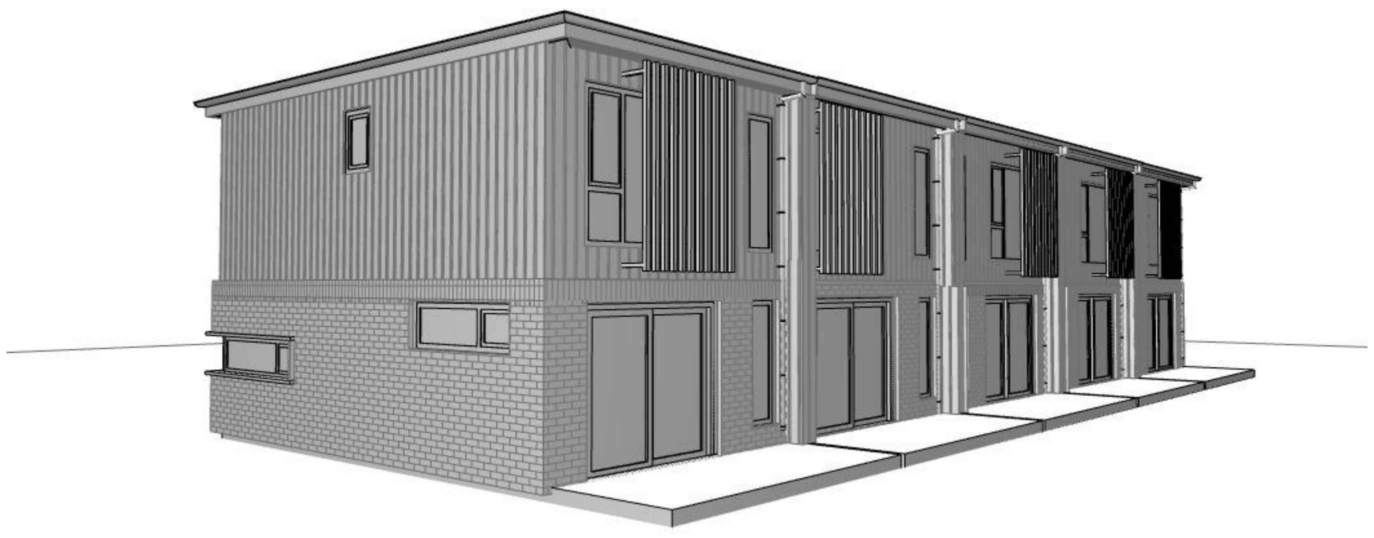
Conditioned floor area:	**66m^2**
Thermal mass type:	**Timber floor - due to insulation on top of slab**
Window to wall ratio:	**22%**
Form factor:	**2.6**

Case study 3 is a terrace of 5x two storey, two bedroom and one bathroom homes. They have a simple form and medium levels of glazing, with a top-insulated concrete slab, timber framing and insulated flat ceilings. It is in an urban location so the site shading levels are higher.

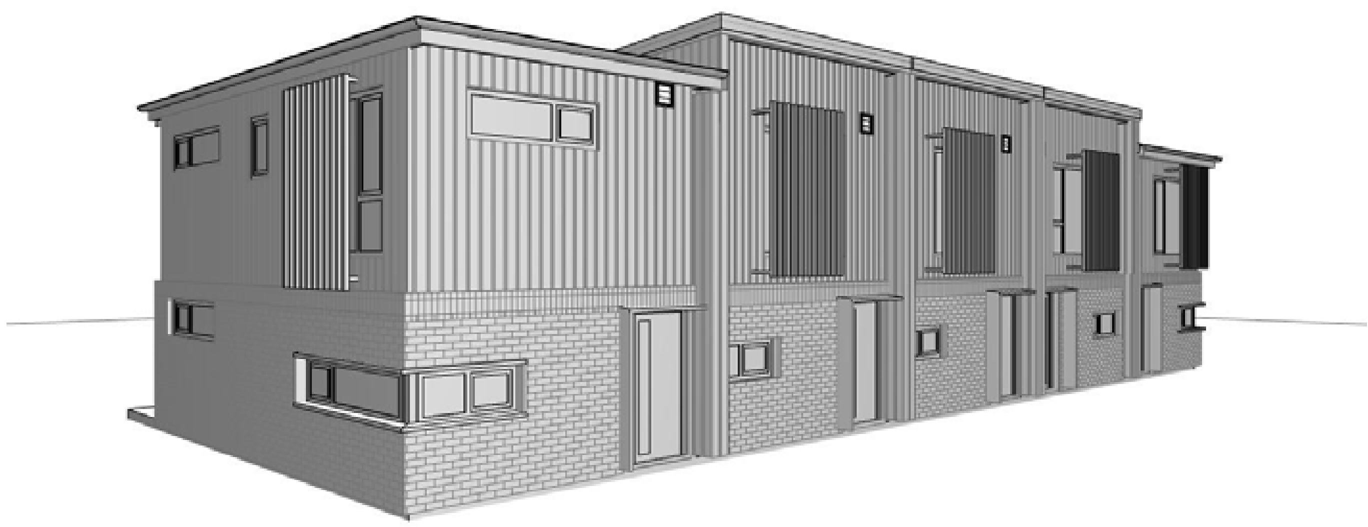
Performance considerations for case study 3

- In this typology there are both north-facing and south-facing units that perform very differently. One is the worst case in heating demand and the other is the worst case in overheating. According to Homestar convention, both scenarios must meet all mandatory minimum targets individually. This may push the level of specifications to be even higher than the examples in case studies 1 and 2.
- When the same set of specifications cannot fulfil the performance targets for both houses, minor tweaks to mitigate either or both buildings may be necessary. Orientation specific glazing selection is the most typical example. Secondly, different design or window sizing can achieve the desired performance outcome although this triggers additional design work.
- Due to the smaller volume to absorb solar gain, the overheating potential is likely to be higher than the example of typologies 1 and 2. Custom vertical shading screens, or external shutters may be required to meet the overheating target. In an urban environment, these devices are often required for privacy reasons, so the overheating targets do not necessarily incur extra cost.
- Brick/schist cladding with larger concrete footing causes a detail where continuous insulation / thermal break cannot be achieved. The resulting thermal bridge will fail the fRsi requirement. The easiest solution is to insulate on top of the slab. This construction method has been used in many passive houses in New Zealand although it is not yet mainstream.
- Concrete slab with insulation over and two storeys of light timber frame on top means the entire house is easy to insulate and is easy to add more insulation to both floor and roof when required (although the increase of the over slab insulation does trigger changes to stud height etc.)
- Concrete slab with insulation over has little to no potential for thermal bridging. In most cases, this will automatically fulfil the fRsi thermal bridge and mould assessment requirement.
- Thermal mass from the concrete slab cannot be counted because there is insulation on top to isolate it. Lightweight timber construction must be selected as thermal mass option in ECCHO.

NB. All units were modelled and based on the results the worst case for heat demand and the worst case for overheating were established – only the results for the worst case for heat demand is shown here, but in reality you would need to submit both for Homestar assessment.

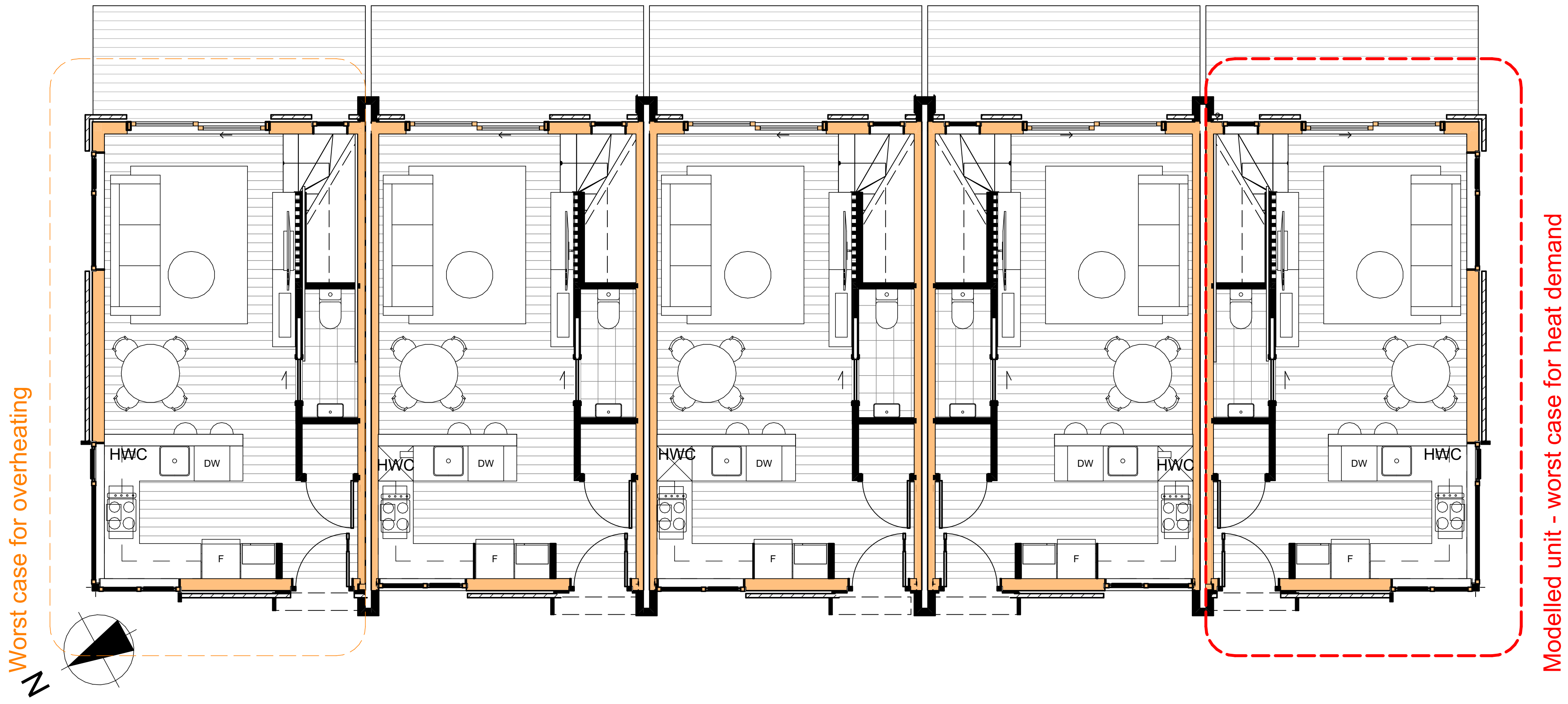


EXTERIOR 1

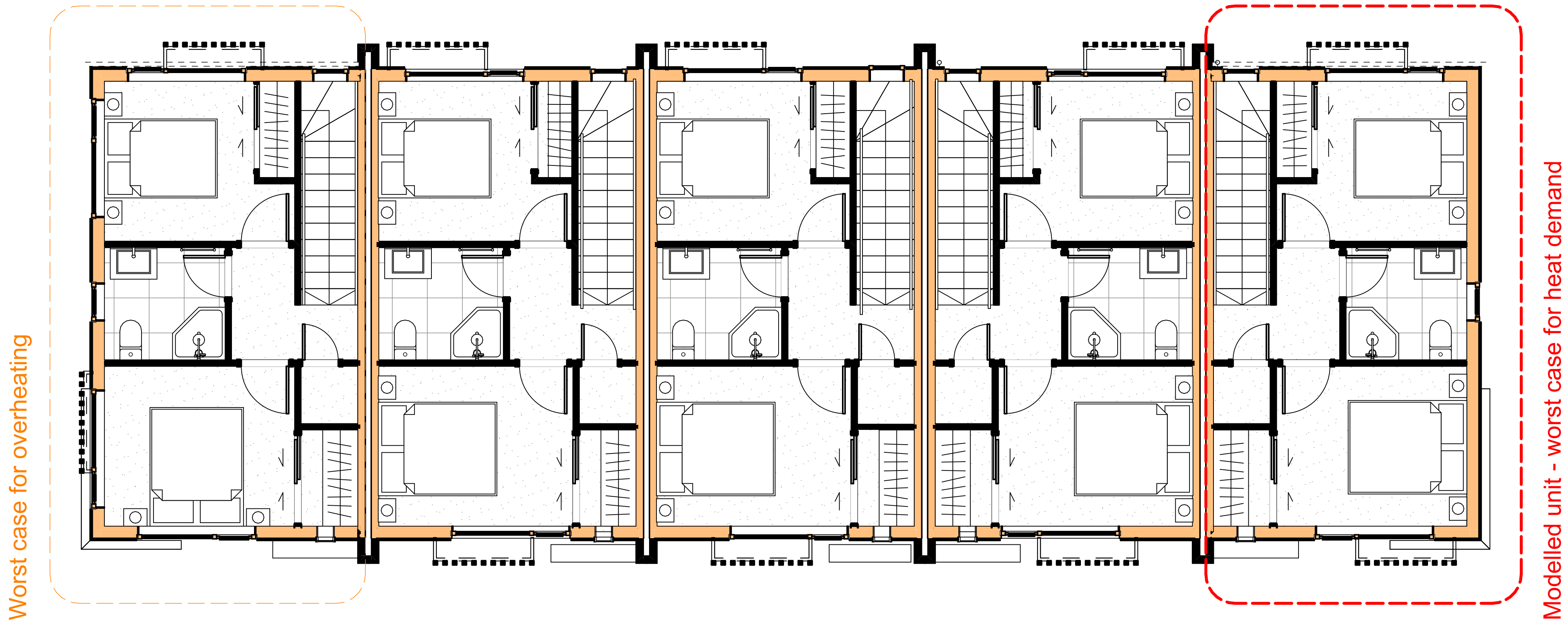


EXTERIOR 2

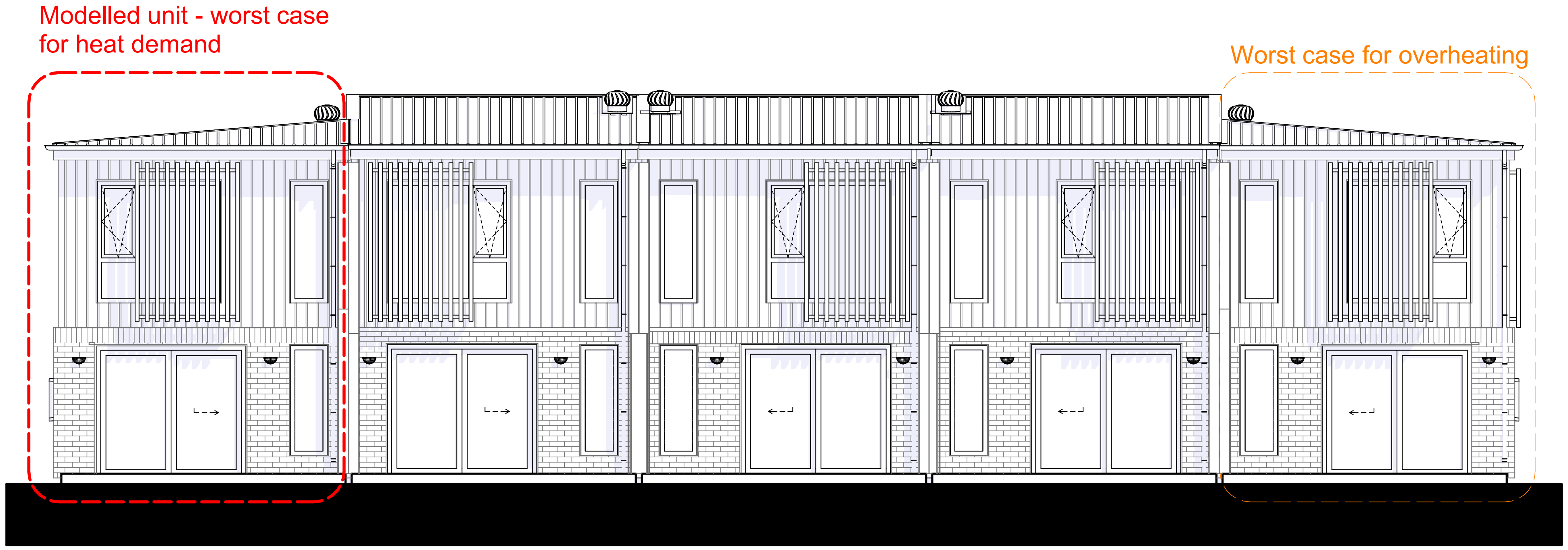
Thermal Envelope



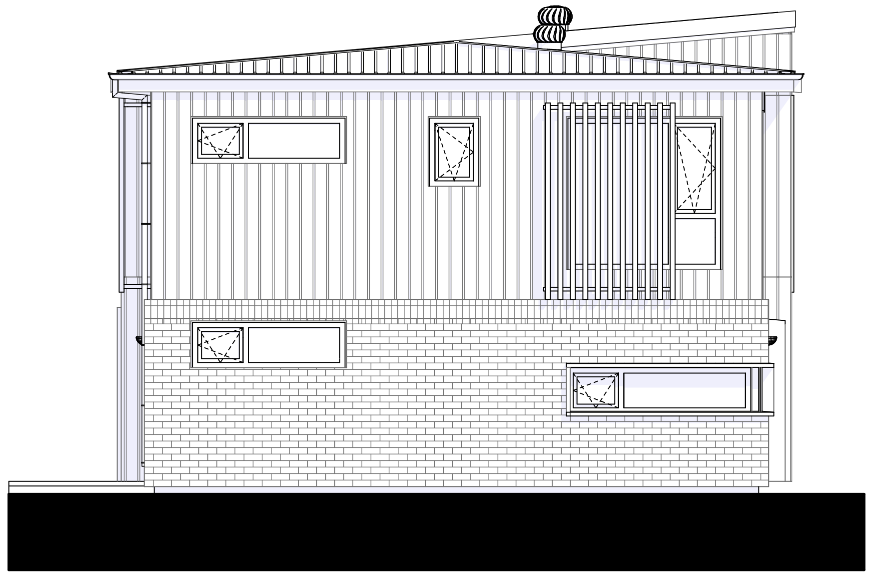
GROUND FLOOR PLAN



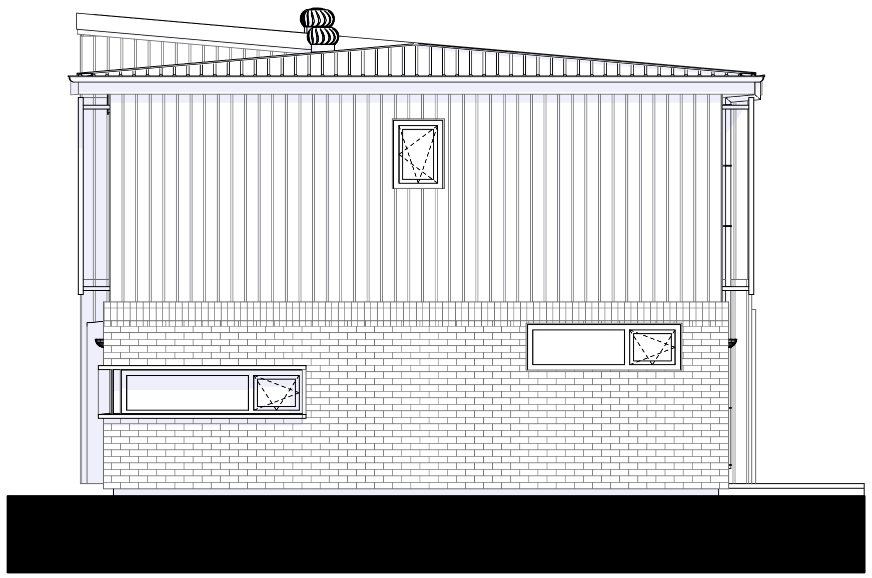
FIRST FLOOR PLAN



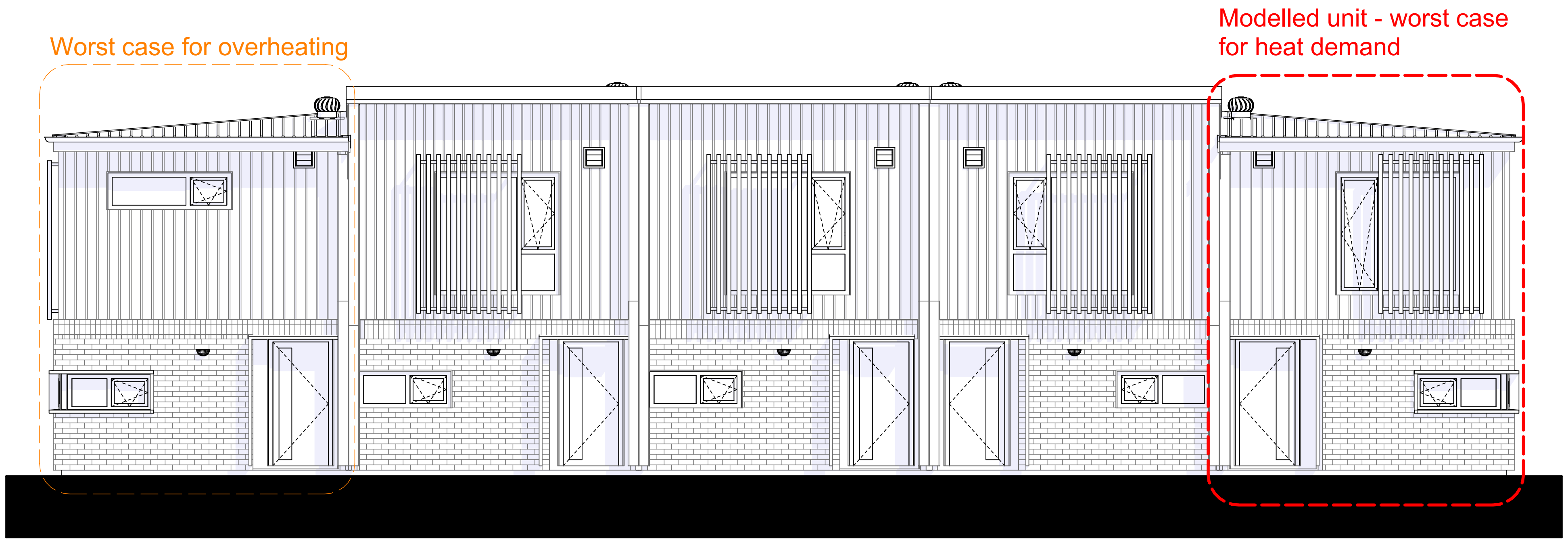
EAST ELEVATION



NORTH ELEVATION

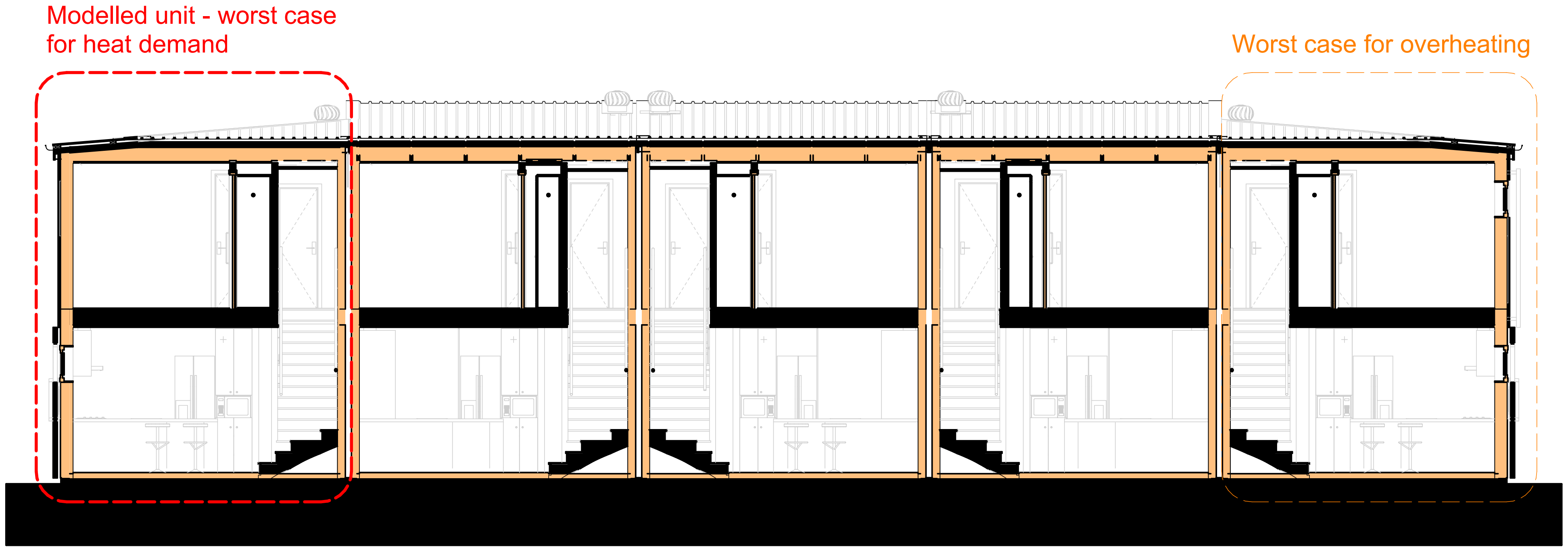


SOUTH ELEVATION

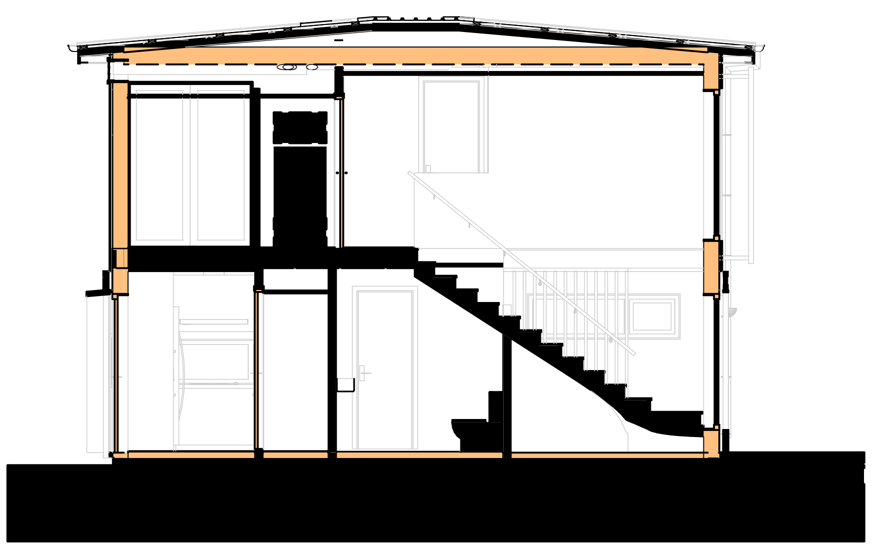


WEST ELEVATION

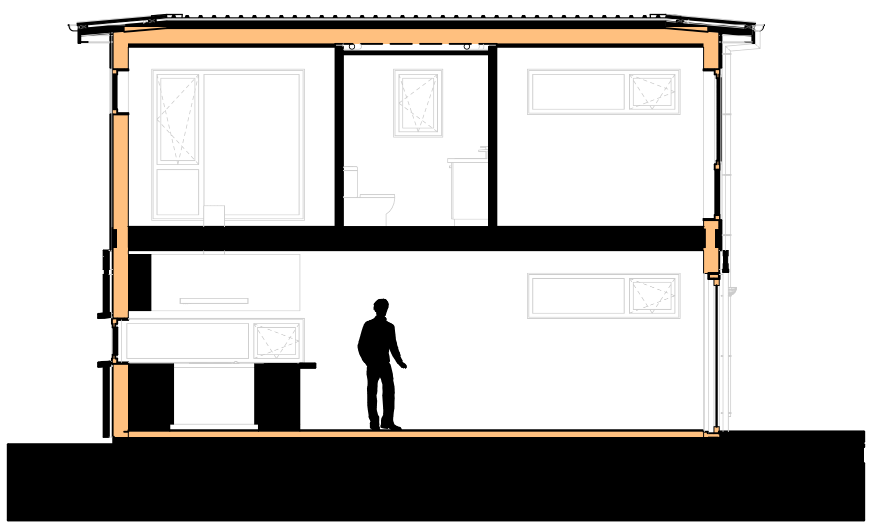
Thermal Envelope



SECTION A - UNIT 1-5



UNIT 1 SECTION 02



UNIT 1 SECTION 03

Case study 3 - Specification

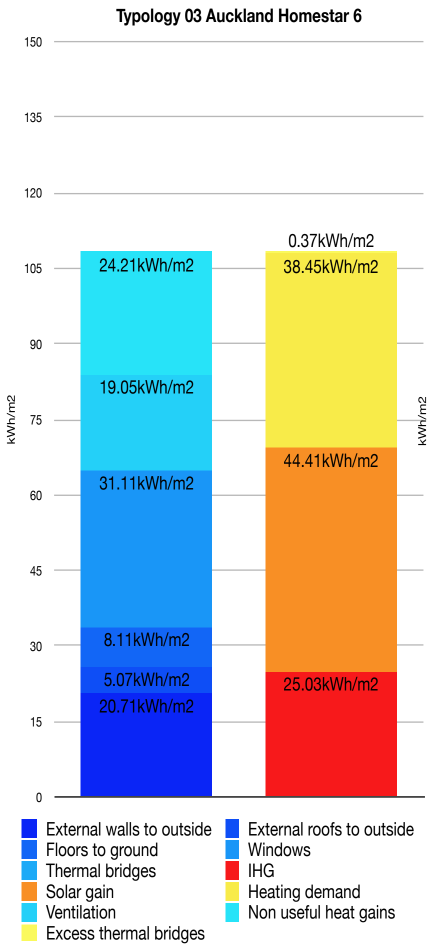
	AKL HS6	WLG HS6	CHCH HS6	AKL HS8	WLG HS8	CHCH HS8
Floor	FLOOR: 50mm XPS on top of slab			FLOOR: 100mm XPS on top of slab		
Wall	WALL: 140 framing (30% timber content)			WALL: 140 framing + 45 service cavity with airtight membrane optimised (15% timber content)		
Roof	ROOF: R5.2 Rafter/Truss roof			ROOF: R6.6 Rafter/Truss roof	ROOF: R7.7 Rafter/Truss roof with insulated ceiling cavity	
Thermal Bridges	HPCD 43: EWFS – Brick veneer waffle pod slab on ground insulation above the slab 140/45 timber frame			HPCD 43: EWFS – Brick veneer waffle pod slab on ground insulation above the slab 140/45 timber frame HPCH 08 EWEC External Wall - External corner 140/45 stud wall no extra timber HPCD 57 TCEA Truss Ceiling Roof Eaves - Truss roof raised heel to maintain insulation thickness		
Window frame	ECCHO Aluminium thermally broken			ECCHO generic PVC frame (recessed)		Optimal PVC frame (supplier specific data, recessed)
Glass	Specific double low-e argon filled glazing based on supplier's specific data (Ug = 1.0, g-value = 0.41)*	ECCHO Double Low-e Arg Best (Ug=1.30)		Specific double low-e argon filled glazing based on supplier's specific data (Ug = 1.1, g-value = 0.35)*	ECCHO Double Low-e Arg Best (Ug=1.30)	ECCHO triple Low-e Arg Best (Ug=0.70, g-value unknown)
Door panel	ECCHO Standard door			Insulated front door panel (supplier specific data)		
Shading objects	Specific designed privacy screen with 60%-70% perforation Window surround on front door and kitchen windows Internal blinds on all windows					
Ventilation	Continuous extract 0% heat recovery efficiency				MVHR 82% heat recovery efficiency	
Airtightness (ACH n50)	5			3.0 with airtight membrane	2.0 with airtight membrane	1.5 with airtight membrane
Heater	50% heat pump (R32 refrigerant) 50% electric panel heater					
Hot water	100% electric HWC			100% heat pump (R744/CO2 refrigerant)		

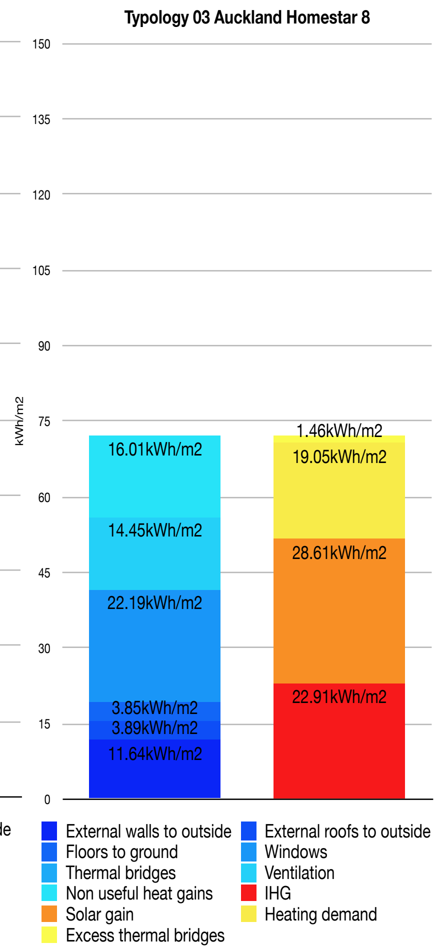
Case study 3 - Results

Auckland

Homestar 6
- Annual space heating demand: 38.5
- Annual electricity demand: 44.2
- Overheating without mechanical cooling: 3.7%

Homestar 8
- Annual space heating demand: 19.0
- Annual electricity demand: 30.8
- Overheating without mechanical cooling: 1.6%

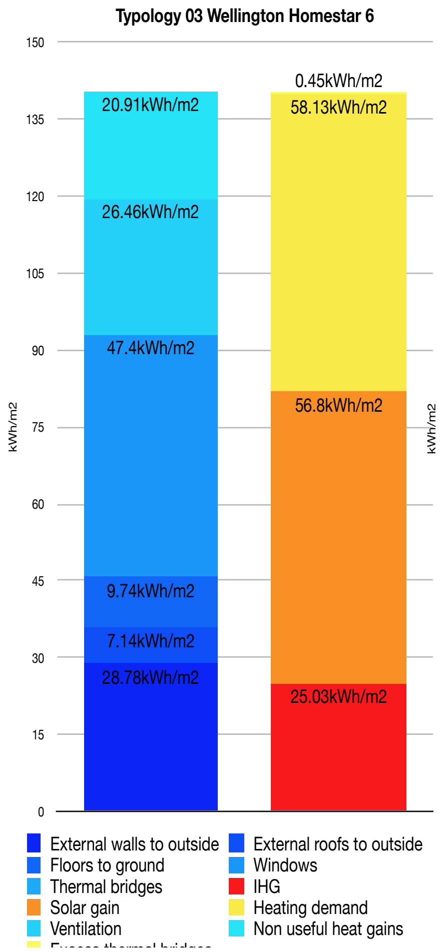


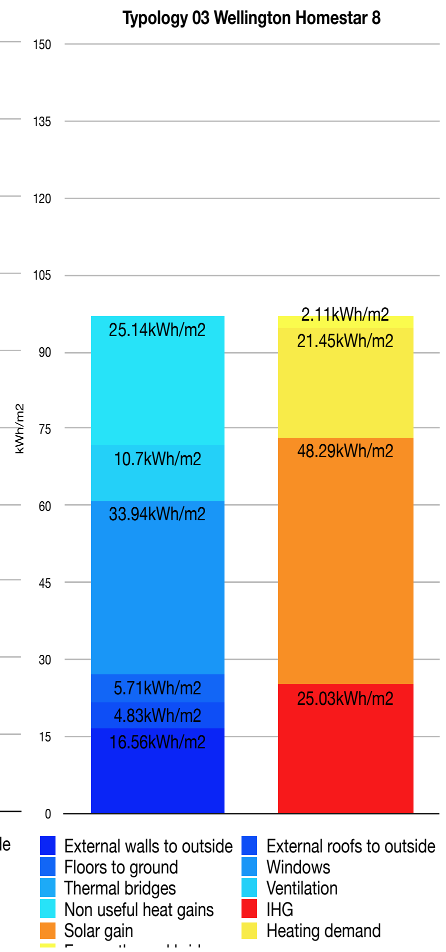


Wellington

Homestar 6
- Annual space heating demand: 58.1
- Annual electricity demand: 59.0
- Overheating without mechanical cooling: 3.2%

Homestar 8
- Annual space heating demand: 21.5
- Annual electricity demand: 34.9
- Overheating without mechanical cooling: 2.1%

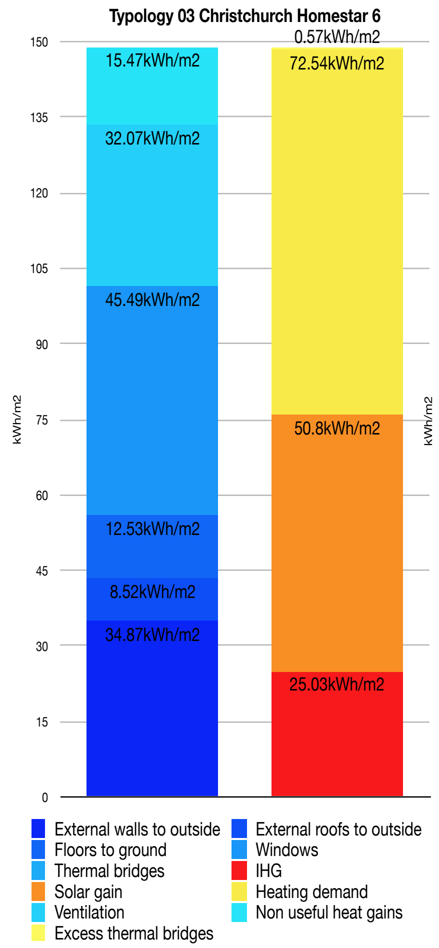


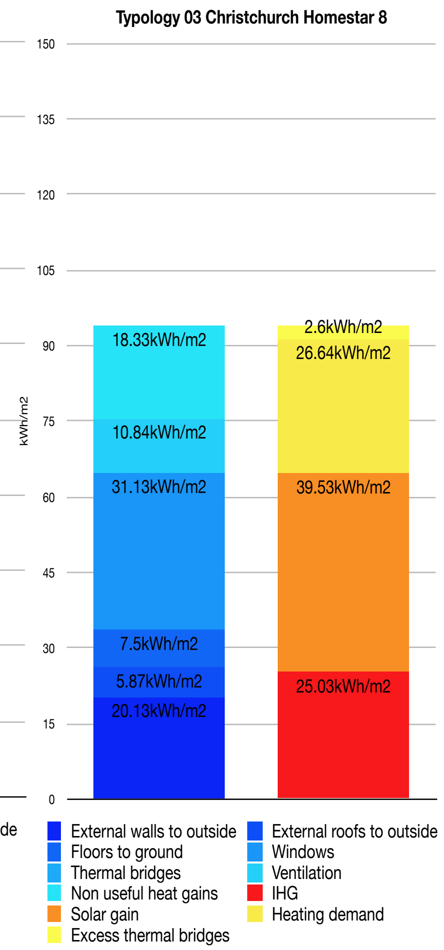


Christchurch

Homestar 6
- Annual space heating demand: 72.5
- Annual electricity demand: 69.9
- Overheating without mechanical cooling: 2.0%

Homestar 8
- Annual space heating demand: 26.6
- Annual electricity demand: 39.2
- Overheating without mechanical cooling: 1.2%





Case study 3 - Costing

The following tables show the different specification upgrades needed from Building Code minimum, to achieve Homestar 6 and Homestar 8 in the three different climate zones, and the related costs for each element.

Case Study 03 - Auckland

	Auckland					
	Building Code Minimum		Homestar 6		Homestar 8	
Building total cost per m2	$3,362		$3,458		$3,572	
Increase from Building Code minimum	0.0%		2.9%		6.2%	
Floor	Standard slab with 100mm EPS under slab (intermittent between thickenings etc) and R1 edge insulation (30mm XPS with render over)	$8,580	50mm XPS on top of slab	$330	100mm XPS on top of slab	$660
Walls	90mm framing with R2.8 insulation	$9,620	140 framing (30% timber content)	$3,330	140 framing + 45 service cavity with airtight membrane optimised (15%)	$4,810
Roof	R7.0 insulation between trusses	$825	R5.2 Rafter/Truss roof	$99	R6.6 Rafter/Truss roof	$264
Window frames	Thermally broken aluminium frame	$11,235	+ trickle vent	$1,600	ECCHO generic PVC frame (recessed)	$3,415
Window glass	Argon filled, double glazing unit. Ug=1.1	$11,385	Specific double low-e argon filled glazing based on supplier's specific data (Ug = 1.0, g-value = 0.41)*	$315	Specific double low-e argon filled glazing based on supplier's specific data (Ug = 1.1, g-value = 0.35)*	$600
Door panel	Standard front door panel	$1,470	No change	-	Insulated front door panel (supplier specific data)	$500
Ventilation	Extractor fan in each bathroom and laundry	$440	Continuous extract 0% heat recovery efficiency	$670	Continuous extract 0% heat recovery efficiency	$670
Airtightness	No airtight construction	$0	5	$0	3 with airtight membrane	$1,500
Heater	1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$3,780	No change	-	No change	-
Hot water	Electric hot water cylinder	$3,950	No change	-	100% heat pump (R744/CO2 refrigerant)	$1,500
Additional cost	-		$6,344		$13,919	

Case Study 03 - Wellington

	Wellington					
	Building Code Minimum		**Homestar 6**		**Homestar 8**	
Building total cost per m2	$3,177		$3,258		$3,533	
Increase from Building Code minimum	0.0%		2.5%		11.2%	
Floor	Standard slab with 100mm EPS under slab (intermittent between thickenings etc) and R1 edge insulation (30mm XPS with render over)	$8,150	50mm XPS on top of slab	$396	100mm XPS on top of slab	$825
Walls	90mm framing with R2.8 insulation	$9,140	140 framing (30% timber content)	$2,640	140 framing + 45 service cavity with airtight membrane optimised (15%)	$3,300
Roof	R7.0 insulation between trusses	$800	No change	-	R7.7 Rafter/Truss roof with insulated ceiling cavity	$990
Window frames	Thermally broken aluminium frame	$10,670	+ trickle vent	$1,600	ECCHO generic PVC frame (recessed)	$3,223
Window glass	Argon filled, double glazing unit. Ug=1.3	$10,820	No change	-	ECCHO Double Low-e Arg Best (Ug=1.30)	$1,700
Door panel	Standard front door panel	$1,410	No change	-	Insulated front door panel (supplier specific data)	$500
Ventilation	Extractor fan in each bathroom and laundry	$440	Continuous extract 0% heat recovery efficiency	$700	MVHR 82% heat recovery efficiency	$10,000
Airtightness	No airtight construction	$0	5	$0	2 with airtight membrane	$1,500
Heater	1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$3,600	No change	-	No change	-
Hot water	Electric hot water cylinder	$3,800	No change	-	100% heat pump (R744/CO2 refrigerant)	$1,500
Additional cost	**-**		**$5,336**		**$23,538**	

Case Study 03 - Christchurch

	Christchurch					
	Building Code Minimum		**Homestar 6**		**Homestar 8**	
Building total cost per m2	$3,302		$3,387		$3,666	
Increase from Building Code minimum	0.0%		2.6%		11.0%	
Floor	Standard slab with 100mm EPS under slab (intermittent between thickenings etc) and R1 edge insulation (30mm XPS with render over)	$8,425	50mm XPS on top of slab	$495	100mm XPS on top of slab	$924
Walls	90mm framing with R2.8 insulation	$9,450	140 framing (30% timber content)	$2,772	140 framing + 45 service cavity with airtight membrane optimised (15%)	$3,630
Roof	R7.0 insulation between trusses	$810	No change	-	R7.7 Rafter/Truss roof with insulated ceiling cavity	$1,155
Window frames	Thermally broken aluminium frame	$11,035	+ trickle vent	$1,600	Optimal PVC frame (supplier specific data, recessed)	$3,332
Window glass	Argon filled, double glazing unit. Ug=1.1	$11,185	No change	-	ECCHO triple Low-e Arg Best (Ug=0.70, g-value unknown)	$1,800
Door panel	Standard front door panel	$1,450	No change	-	Insulated front door panel (supplier specific data)	$500
Ventilation	Extractor fan in each bathroom and laundry	$440	Continuous extract 0% heat recovery efficiency	$750	MVHR 82% heat recovery efficiency	$10,500
Airtightness	No airtight construction	$0	5	$0	1.5 with airtight membrane	$1,620
Heater	1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$3,700	No change	-	No change	-
Hot water	Electric hot water cylinder	$3,880	No change	-	100% heat pump (R744/CO2 refrigerant)	$1,500
Additional cost	-		$5,617		$24,037	

Case study 4 - Multi-unit apartments

Conditioned floor area: **79m2**

Thermal mass type: **Timber floor on piles for upper storey units and concrete slab, single level timber for ground floor units**

Window to wall ratio: **22% (based on south-facing ground floor unit as worst case)**

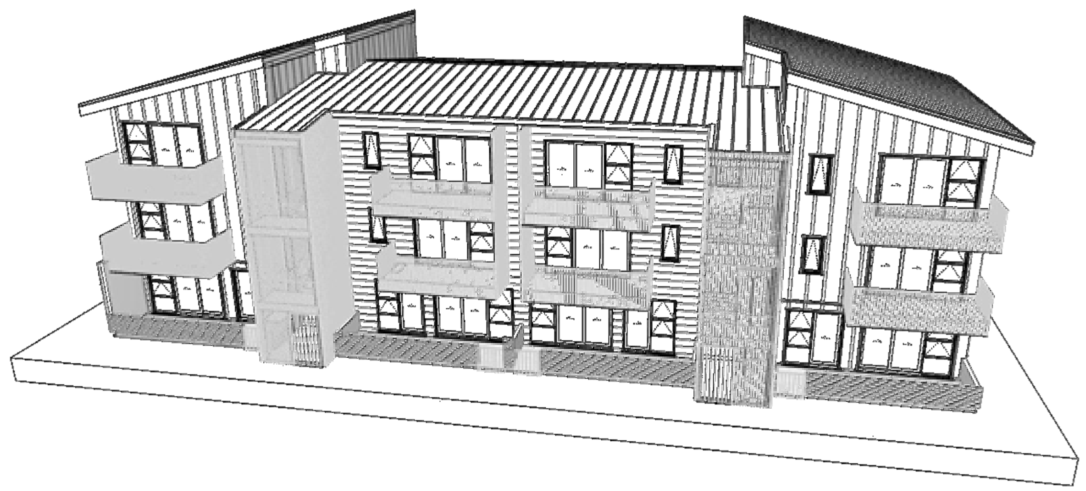
Form factor: **2.4 (based on south-facing ground floor unit as worst case)**

Case study 4 is a block of 12 two bedroom, two bathroom apartments. The block is constructed with a concrete slab ground floor, and timber frame for the upper floors. It is in an urban location so the site shading levels are higher.

Performance considerations for case study 4

- There are multiple scenarios to assess before we are able to determine the actual worst-case for heating demand and overheating.
- Ground level south > It is reasonable to assume this is the worst case for heating demand because there is a larger heat loss area while having limited solar gain.
- Level 1 north > Assumption cannot be made without modelling because there is small heat loss area (no floor or roof as part of the thermal envelope) while having large solar gain.
- Level 1 east-west > Assumption cannot be made without modelling because there is minimal heat loss area while having east and west exposure.
- Level 2 north > Assumption cannot be made without modelling because there is a larger heat loss area while having the highest heat gain.
- Additional thermal mass variation due to separated floors.
- Ground floor units have a concrete slab floor and single level timber walls, level 1 and level 2 units have a timber floor and timber walls.
- Ground level units' thermal envelopes have large percentage of floor area and no roof area.
- Level 1 units' thermal envelopes have no floor, no roof, and 100% walls.
- Level 2 units' thermal envelopes have large percentage of roof area and no floor area.
- Increased importance on glazing selection. Due to the limited ability to create specific floor, wall, roof, and window frame solutions, glazing selections become critically important to ensure consistent and Homestar compliant performance across all apartment units. Not only orientation specific but also floor specific glazing selection may be required.
- Overall, it is easier to keep apartment units warm but harder to manage overheating.

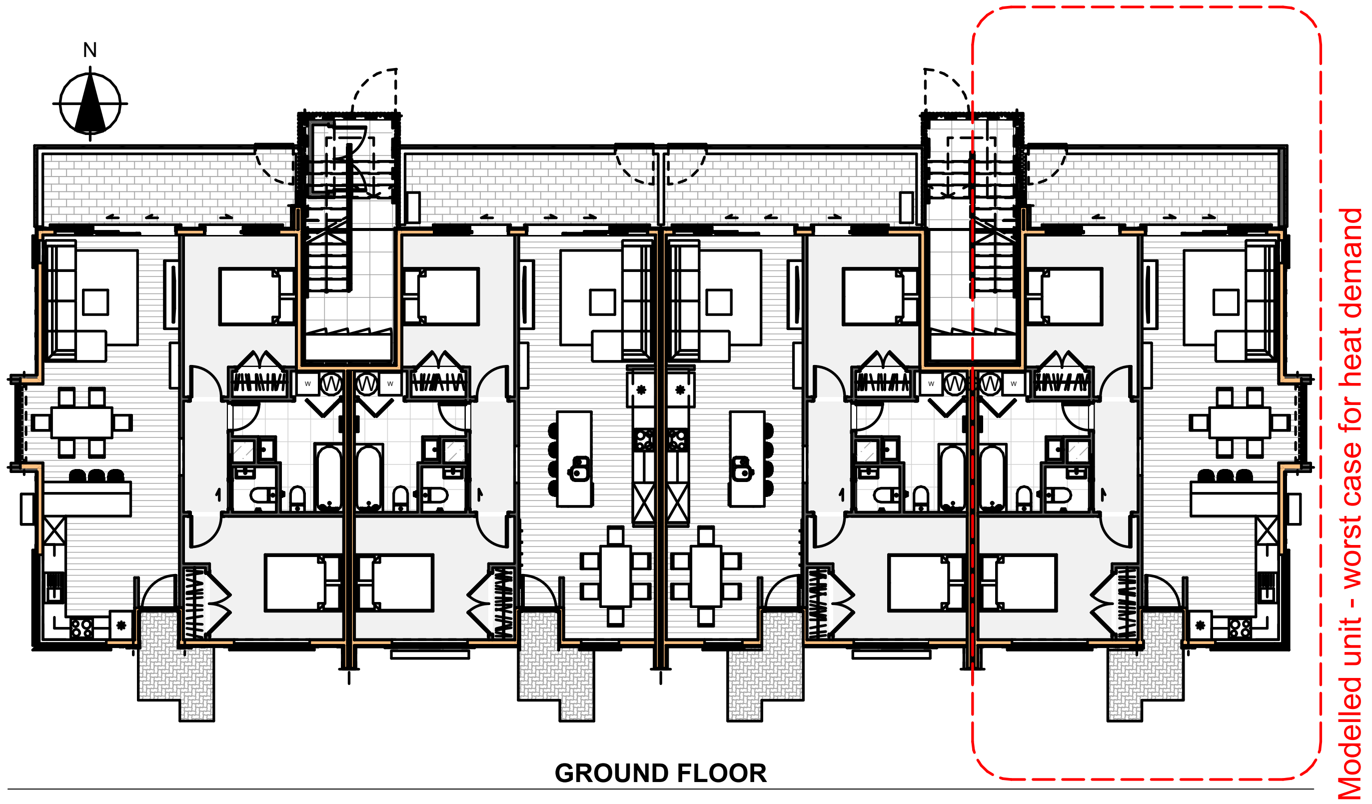
NB. All units were modelled and based on the results the worst case for heat demand and the worst case for overheating were established – only the results for the worst case for heat demand is shown here, but in reality you would need to submit both for Homestar assessment.



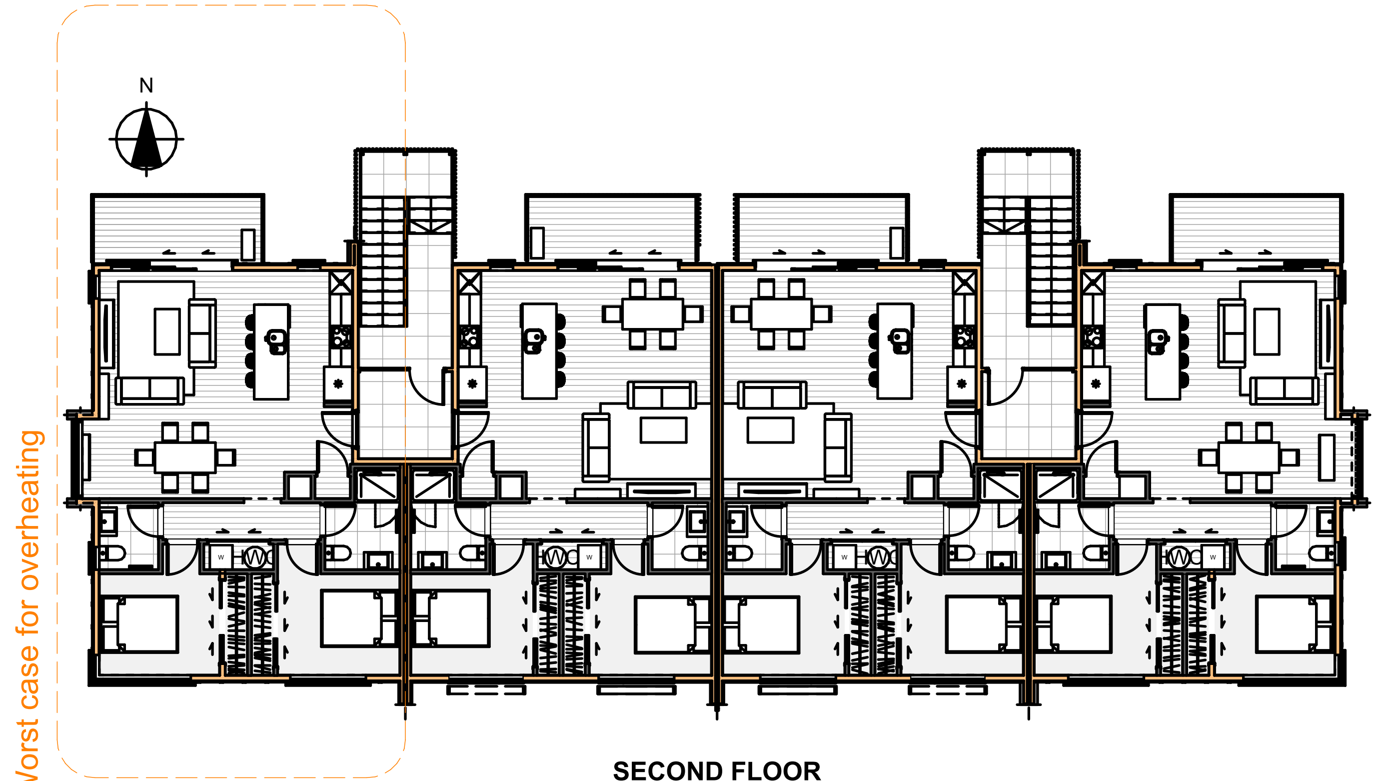
3D VIEW 01

3D VIEW 02

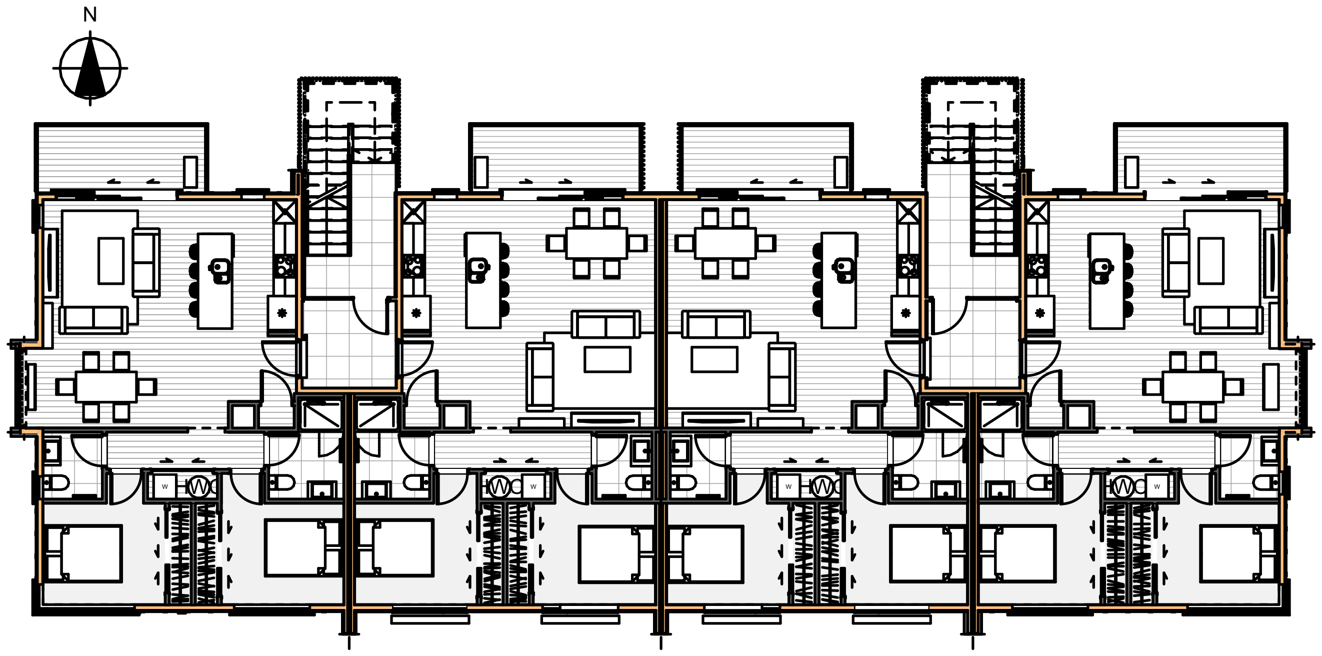
Thermal Envelope



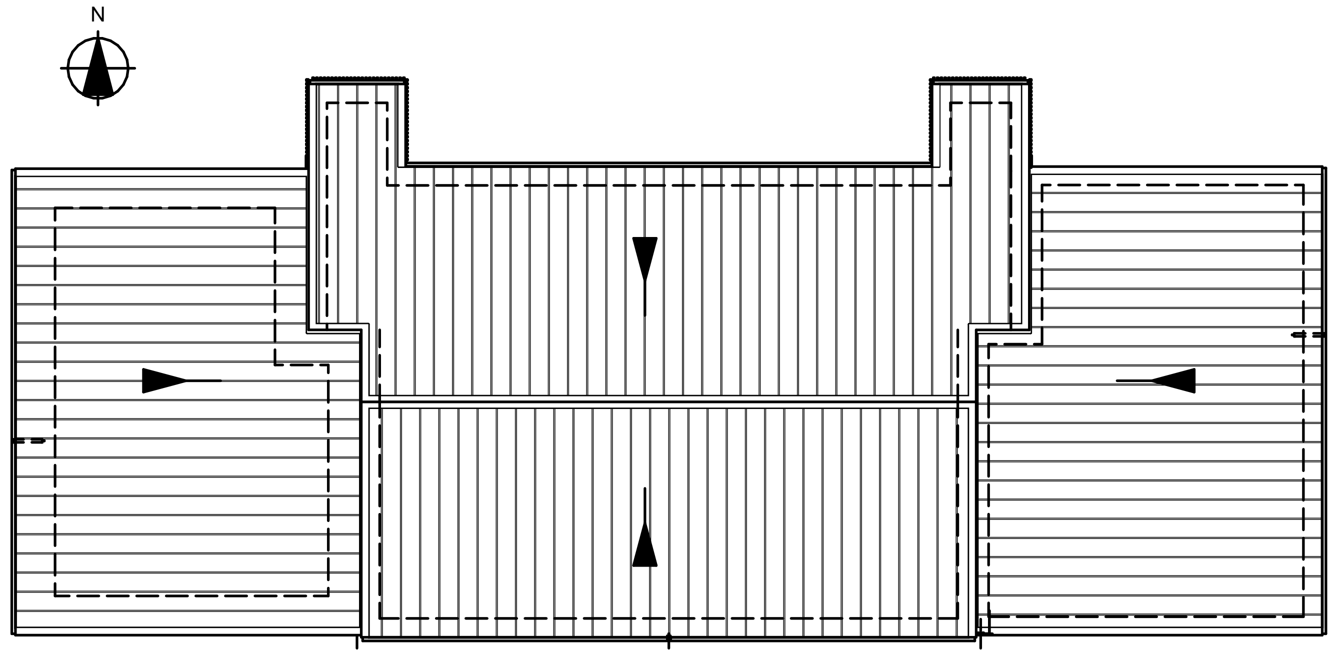
GROUND FLOOR



SECOND FLOOR



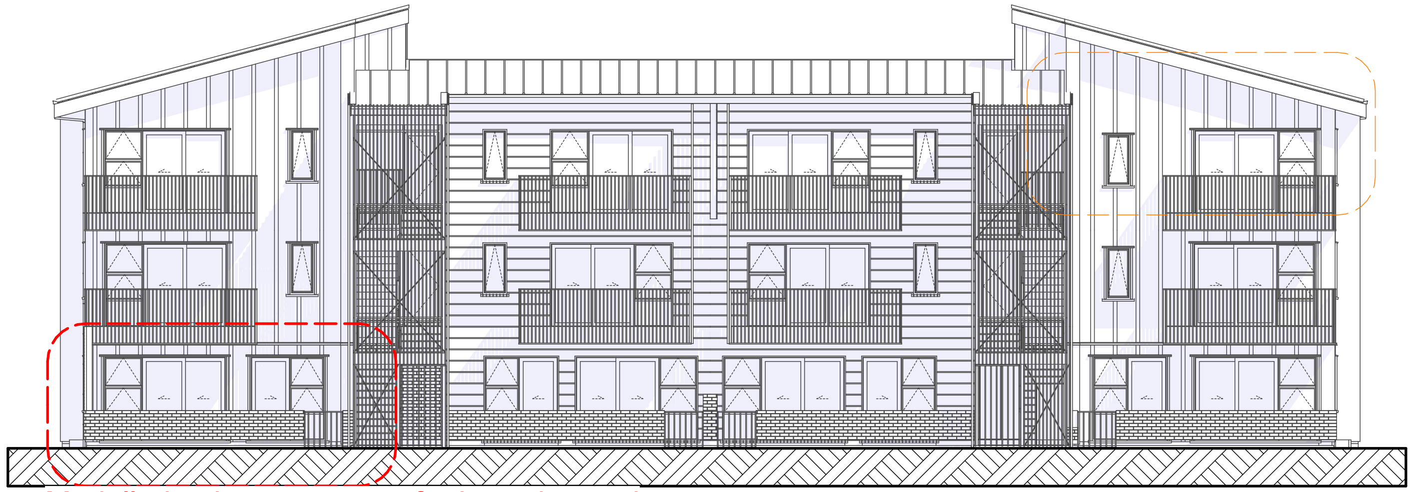
FIRST FLOOR



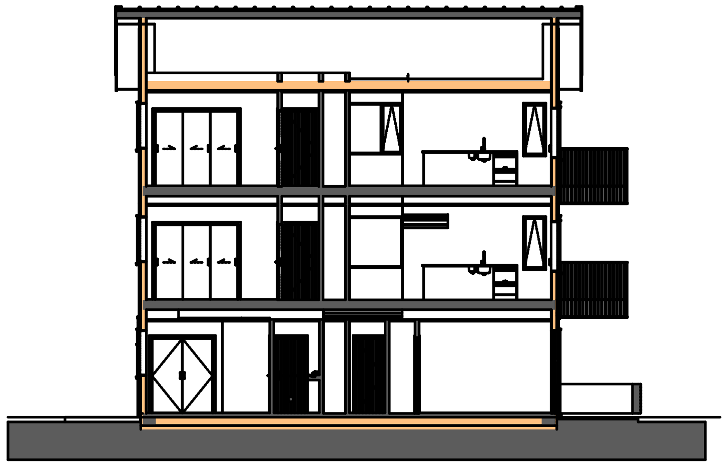
ROOF

Thermal Envelope

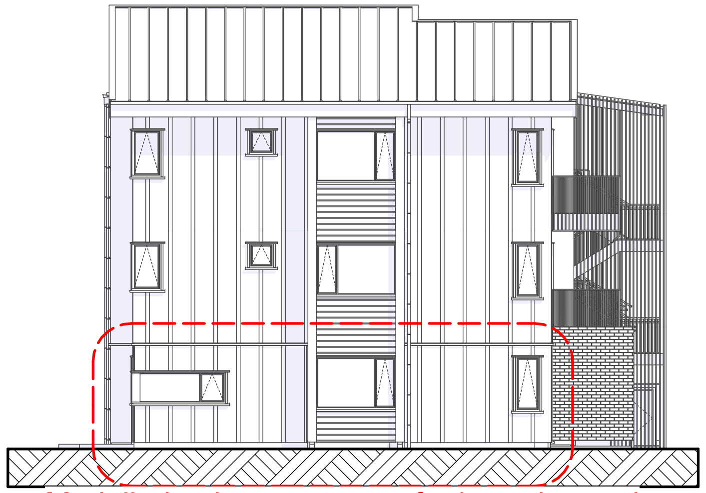
SECTION A



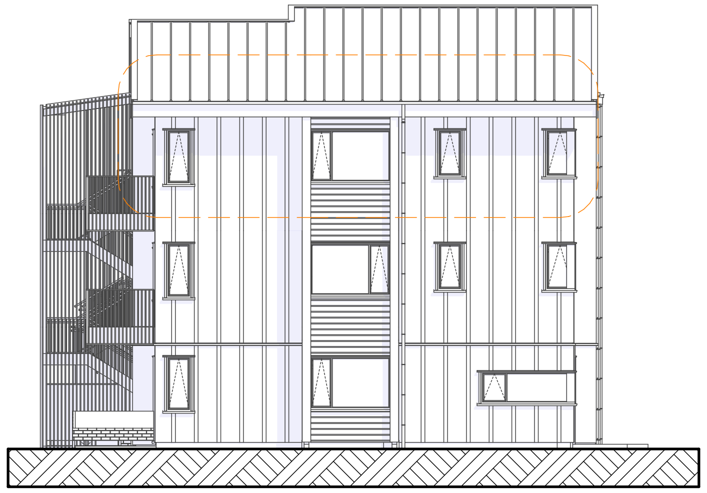
NORTH ELEVATION PROPOSED



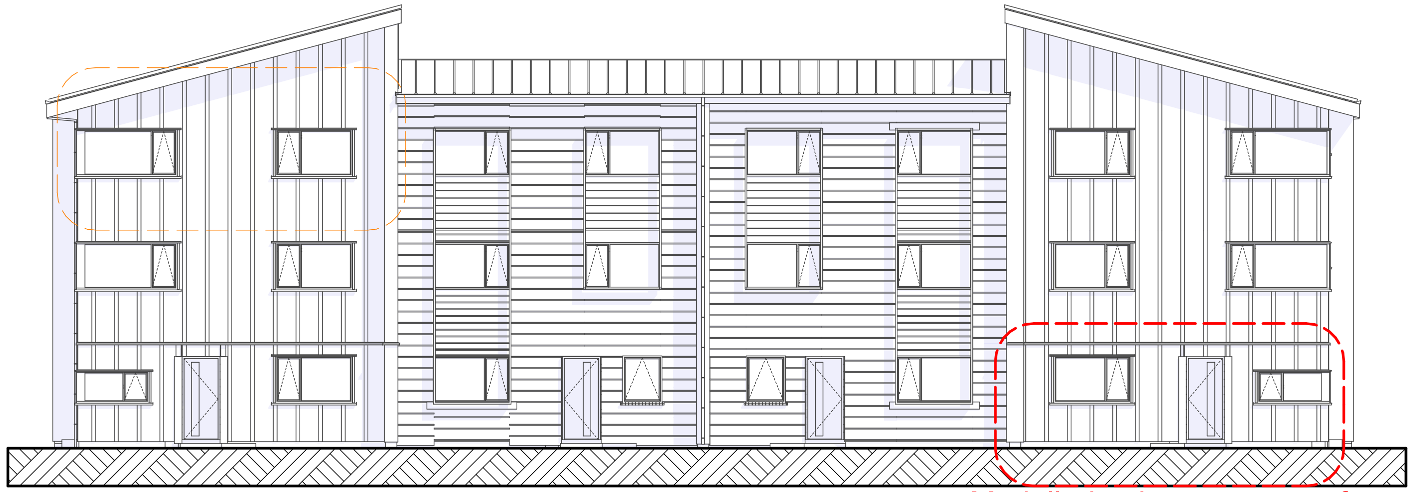
SECTION B



EAST ELEVATION PROPOSED



WEST ELEVATION PROPOSED



SOUTH ELEVATION PROPOSED

Case study 4 - Specification

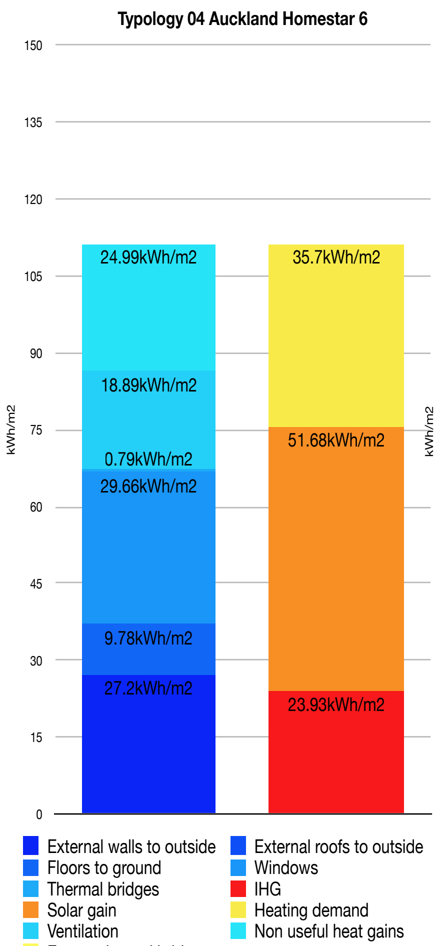
<table>
<tr><th></th><th>AKL HS6</th><th>WLG HS6</th><th>CHCH HS6</th><th>AKL HS8</th><th>WLG HS8</th><th>CHCH HS8</th></tr>
<tr><td>Floor</td><td colspan="6">FLOOR: Waffle Slab 220 solid pods with ribs and 50mm EPS under</td></tr>
<tr><td>Wall</td><td colspan="2">WALL: 90 framing (30% timber content)</td><td>WALL: 140 framing (30% timber content)</td><td colspan="3">WALL: 140 framing + 45 service cavity with airtight membrane optimised (15% timber content)</td></tr>
<tr><td>Roof</td><td colspan="3">ROOF: R5.2 Rafter/Truss roof</td><td colspan="3">ROOF: R6.6 Rafter/Truss roof with insulated ceiling cavity</td></tr>
<tr><td>Thermal Bridges</td><td colspan="2">ECCHO fully insulated raft slab 300 90mm timber clad</td><td>ECCHO fully insulated slab 300 140mm timber clad</td><td colspan="3">HPCD 39: EWFS – 140/45 stud wall insulated waffle pod slab edge insulation and full insulation under ribs
HPCH 08 EWEC External Wall - External corner 140/45 stud wall no extra timber
HPCD 57 TCEA Truss Ceiling Roof Eaves - Truss roof raised heel to maintain insulation thickness</td></tr>
<tr><td>Window frame</td><td colspan="3">ECCHO Aluminium thermally broken</td><td>ECCHO Aluminium thermally broken (recessed)</td><td>ECCHO generic PVC frame (recessed)</td><td>Optimal PVC frame (supplier specific data, recessed)</td></tr>
<tr><td rowspan="2">Glass</td><td>L1 & L2 units: Specific double low-e argon filled glazing based on supplier’s specific data (Ug = 1.1, g-value = 0.35)*</td><td colspan="2" rowspan="2">ECCHO Double Low-e Arg Best (Ug=1.30)</td><td>L1 & L2 units: Specific double low-e argon filled glazing based on supplier’s specific data (Ug = 1.1, g-value = 0.35)*</td><td rowspan="2">ECCHO Double Low-e Arg Best (Ug=1.30)</td><td rowspan="2">Triple Low-e Arg Exceptional (supplier specific data, Ug=0.60, g=0.49)</td></tr>
<tr><td>GL units: ECCHO Double Low-e Arg Best (Ug=1.30)</td><td>GL units: ECCHO Double Low-e Arg Best (Ug=1.30)</td></tr>
<tr><td>Door panel</td><td colspan="5">ECCHO Standard door</td><td>Insulated front door panel (supplier specific data)</td></tr>
<tr><td>Shading objects</td><td colspan="6">Roof overhang and balcony overhang
Stairs wing wall and vertical privacy screens
Internal blinds on all windows</td></tr>
<tr><td>Ventilation</td><td colspan="4">Continuous extract 0% heat recovery efficiency</td><td colspan="2">MVHR 82% heat recovery efficiency</td></tr>
<tr><td>Airtightness (ACH n50)</td><td colspan="3">5</td><td colspan="2">2.0 with airtight membrane</td><td>1.5 with airtight membrane</td></tr>
<tr><td>Heater</td><td colspan="6">50% heat pump (R32 refrigerant)
50% electric panel heater</td></tr>
<tr><td>Hot water</td><td colspan="3">100% electric HWC</td><td colspan="3">100% heat pump (R744/CO2 refrigerant)</td></tr>
</table>

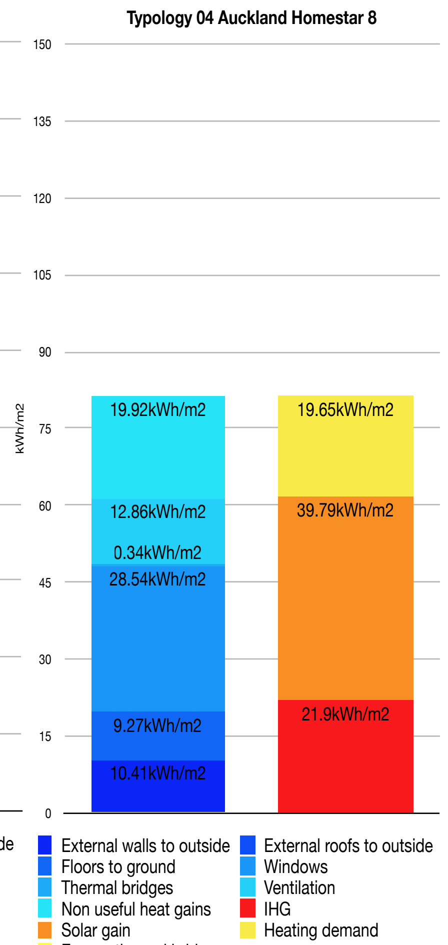
Case study 4 - Results

Auckland

Homestar 6
- Annual space heating demand: 35.7
- Annual electricity demand: 40.3
- Overheating without mechanical cooling: 3.2%

Homestar 8
- Annual space heating demand: 19.6
- Annual electricity demand: 29.0
- Overheating without mechanical cooling: 4.9%

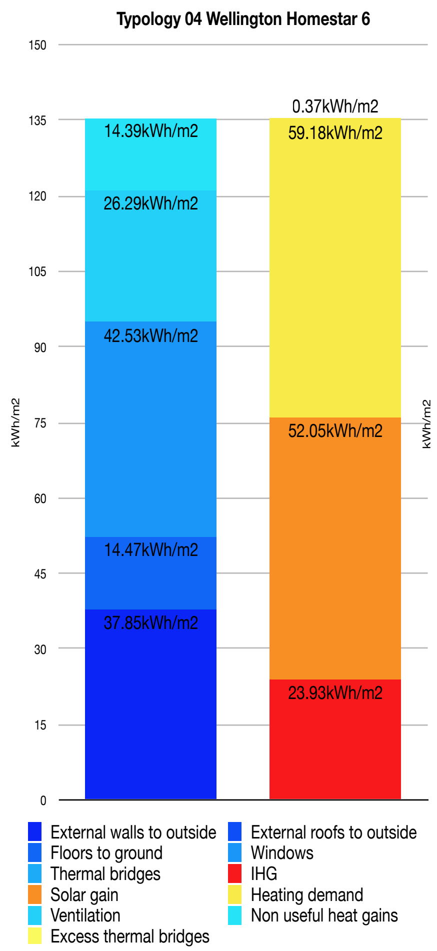


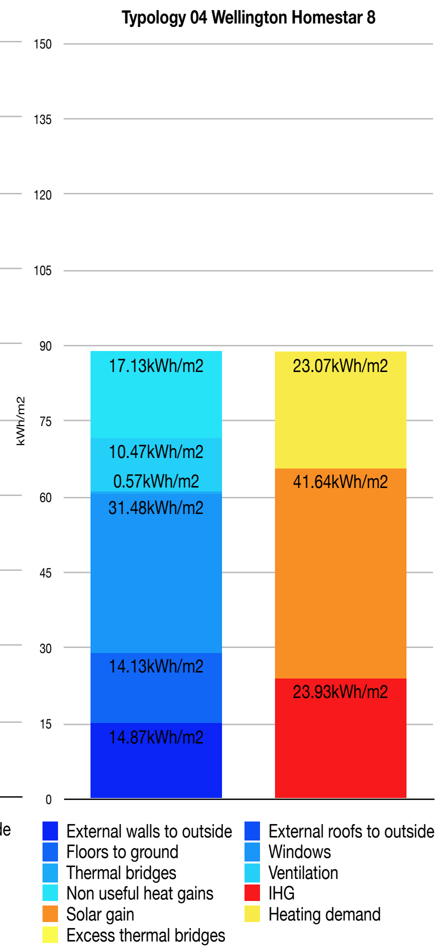


Wellington

Homestar 6
- Annual space heating demand: 59.2
- Annual electricity demand: 57.7
- Overheating without mechanical cooling: 1.0%

Homestar 8
- Annual space heating demand: 23.1
- Annual electricity demand: 34.1
- Overheating without mechanical cooling: 0.7%

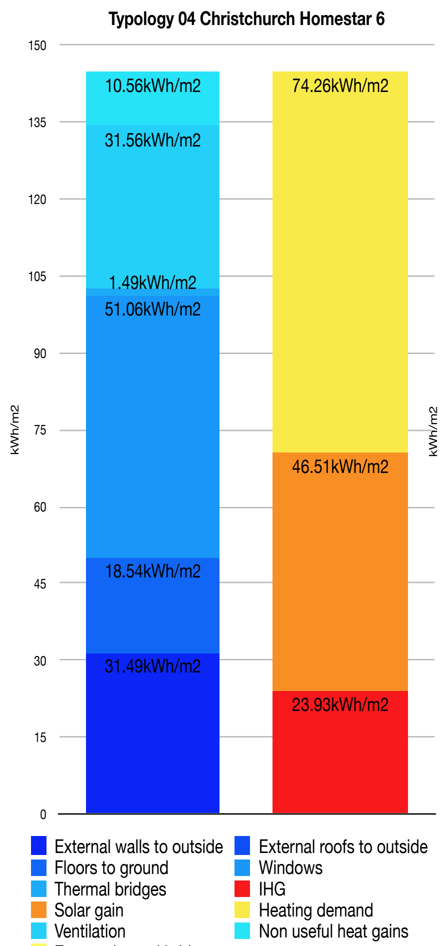


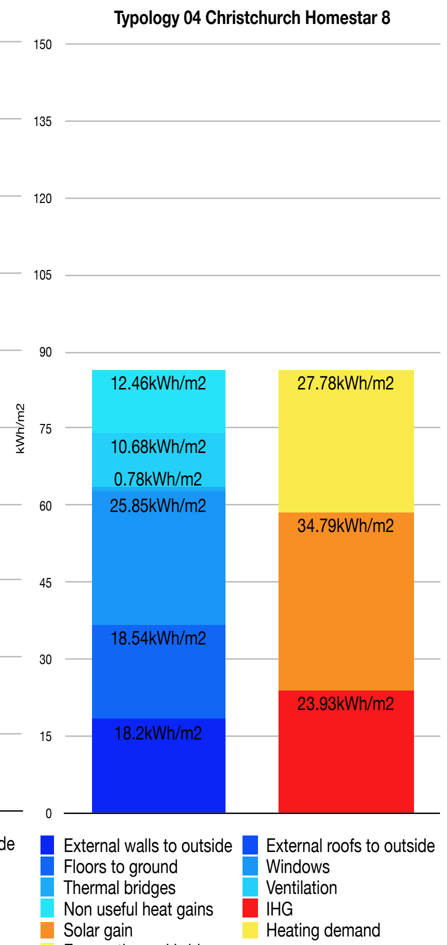


Christchurch

Homestar 6
- Annual space heating demand: 74.3
- Annual electricity demand: 69
- Overheating without mechanical cooling: 0.5%

Homestar 8
- Annual space heating demand: 27.8
- Annual electricity demand: 37.9
- Overheating without mechanical cooling: 0.1%





Case study 4 - Costing

The following tables show the different specification upgrades needed from Building Code minimum, to achieve Homestar 6 and Homestar 8 in the three different climate zones, and the related costs for each element.

Case Study 04 - Auckland						
	Auckland					
	Building Code Minimum		Homestar 6		Homestar 8	
Building total cost per m2	$4,315		$4,395		$4,639	
Increase from Building Code minimum	0.0%		1.9%		7.5%	
Floor	Raft slab with 220 pods and R1 edge insulation (30mm XPS with render over)	$23,305	Additional 50mm EPS under	$1,975	Additional 50mm EPS under	$1,750
Walls	90mm framing with R2.8 insulation - 30% timber content	$16,900	No change	-	140 framing + 45 service cavity with airtight membrane optimised (15%)	$5,850
Roof	R7.0 insulation between trusses	$2,054	R5.2 Rafter/Truss roof	$237	R6.6 Rafter/Truss roof with insulated ceiling cavity	$632
Window frames	ECCHO Aluminium thermally broken	$13,800	+ trickle vent	$1,800	ECCHO Aluminium thermally broken (recessed)	$1,840
Window glass	Argon filled, double glazing unit. Ug=1.1	$15,100	L1 & L2 units: Specific double low-e argon filled glazing based on supplier's specific data (Ug = 1.1, g-value = 0.35)* GL units: ECCHO Double Low-e Arg Best (Ug=1.30)	$1,500	L1 & L2 units: Specific double low-e argon filled glazing based on supplier's specific data (Ug = 1.1, g-value = 0.35)* GL units: ECCHO Double Low-e Arg Best (Ug=1.30)	$1,500
Door panel	Standard front door panel	$1,470	No change	-	No change	-
Ventilation	Extractor fan in each bathroom and laundry	$440	Continuous extract 0% heat recovery efficiency	$800	Continuous extract 0% heat recovery efficiency	$800
Airtightness	No airtight construction - assumed 5ach	$0	No change	-	2.0 with airtight membrane	$3,250
Heater	1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$3,780	No change	-	No change	-
Hot water	Electric hot water cylinder	$3,950	No change	-	100% heat pump (R744/CO2 refrigerant)	$10,000
Additional cost	-		$6,312		$25,622	

Case Study 04 - Wellington						
	Wellington					
	Building Code Minimum		Homestar 6		Homestar 8	
Building total cost per m2	$4,080		$4,138		$4,442	
Increase from Building Code minimum	0.0%		1.4%		8.9%	
Floor	Raft slab with 220 pods and R1 edge insulation (30mm XPS with render over)	$22,140	Additional 50mm EPS under	$1,975	Additional 50mm EPS under	$1,750
Walls	90mm framing with R2.8 insulation - 30% timber content	$16,055	No change	-	140 framing + 45 service cavity with airtight membrane optimised (15%)	$5,850
Roof	R7.0 insulation between trusses	$1,951	R5.2 Rafter/Truss roof	$237	R6.6 Rafter/Truss roof with insulated ceiling cavity	$632
Window frames	ECCHO Aluminium thermally broken	$13,110	+ trickle vent	$1,600	ECCHO generic PVC frame (recessed)	$4,118
Window glass	Argon filled, double glazing unit. Ug=1.3	$14,345	No change	-	ECCHO Double Low-e Arg Best (Ug=1.30)	$1,500
Door panel	Standard front door panel	$1,410	No change	-	No change	-
Ventilation	Extractor fan in each bathroom and laundry	$440	Continuous extract 0% heat recovery efficiency	$800	MVHR 82% heat recovery efficiency	$10,000
Airtightness	No airtight construction - assumed 5ach	$0	No change	-	2.0 with airtight membrane	$3,250
Heater	1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$3,600	No change	-	No change	-
Hot water	Electric hot water cylinder	$3,800	No change	-	100% heat pump (R744/ CO_2 refrigerant)	$1,500
Additional cost	-		$4,612		$28,600	

Case Study 04 - Christchurch

	Christchurch					
	Building Code Minimum		Homestar 6		Homestar 8	
Building total cost per m2	$4,237		$4,373		$4,653	
Increase from Building Code minimum	0.0%		3.2%		9.8%	
Floor	Raft slab with 220 pods and R1 edge insulation (30mm XPS with render over)	$22,885	Additional 50mm EPS under	$1,975	Additional 50mm EPS under	$1,750
Walls	90mm framing with R2.8 insulation	$16,595	140 framing (30% timber content)	$5,850	140 framing + 45 service cavity with airtight membrane optimised (15%)	$8,450
Roof	R7.0 insulation between trusses	$2,107	R5.2 Rafter/Truss roof	$316	R6.6 Rafter/Truss roof with insulated ceiling cavity	$711
Window frames	ECCHO Aluminium thermally broken	$13,552	+ trickle vent	$1,760	Optimal PVC frame (supplier specific data, recessed)	$4,257
Window glass	Low e argon filled, double glazing unit. Ug=1.1	$14,828	No change	-	Triple Low-e Arg Exceptional (supplier specific data, Ug=0.60, g=0.49)	$1,840
Door panel	Standard front door panel	$1,450	No change	-	Insulated door panel	$500
Ventilation	Extractor fan in each bathroom and laundry	$440	Continuous extract 0% heat recovery efficiency	$850	MVHR 82% heat recovery efficiency	$10,500
Airtightness	No airtight construction - assumed 5ach	$0	No change	-	1.5 with airtight membrane	$3,380
Heater	1 X 1kW electric panel heater in each bedroom and 1 X 5kW heat pump in living room (Note: this is not a code requirement but a healthy home minimum standard for rental property and reflect most new developments)	$3,720	No change	-	No change	-
Hot water	Electric hot water cylinder	$3,880	No change	-	100% heat pump (R744/ CO2 refrigerant)	$1,500
Additional cost	-		$10,751		$32,888	

Glossary

Air and vapour control layer (AVCL)	This is a layer designed to control the air and vapour flow through a building assembly. Examples include specialist membranes and taped plywood or oriented strand board (OSB).
Air changes	The number of times that the total air volume in a home is completely removed and replaced with outdoor air, usually expressed per hour.
Airtightness	An assessment of the amount of unintended air leaks in the building envelope. Homestar uses the envelope area (Air permeability qE50 from ISO9972) as a reference for airtightness: m3 of air loss per m2 of envelope per hour @ 50pa pressure.
Annual electricity demand	'Delivered' energy includes everything associated with operational energy - excludes plug loads/appliances. It takes into account efficiency of any systems (e.g. demand might be 30 kWh/m²/yr, but using a heat pump with COP=3 means delivered energy is only 10 kWh/m²/yr).
Annual space heating demand/ heat demand	The amount of energy required to keep the building interior at a specified temperature.
Balanced ventilation	A balanced pressure ventilation system uses two fans to bring in the same amount of air as it removes. This ensures there is no pressure on the building envelope so no air is pushed or pulled through the building fabric.
Building performance	In the context of this guide this refers to the overall energy efficiency, user comfort and long-term durability of a building.
Climate zone	Designation of areas within New Zealand that share similar climatic characteristics.
CLT	Cross laminated timber - a form of mass timber construction.
Cold roof	Conventional New Zealand roof build-up where the structure of the roof (e.g. the rafters) is outside the thermal envelope.
Conditioned floor area (CFA)	Space within the thermal envelope of the dwelling that could maintain a temperature band of between 20-25°C for 365 days of the year. Refer to the Homestar Technical Manual for more details.
Continuous extract ventilation	Whole-dwelling ventilation system that extracts air continuously at a low rate.
Decentralised ventilation	A ventilation system that uses several fans in different locations to deliver and remove air in a building.
Ducted ventilation	A ventilation system that uses ducts to deliver and remove air in a building, with a single central fan unit.
ECCHO	The Homestar® energy analysis tool, ECCHO (Energy and Carbon Calculator for Homes), is a web app that allows users to calculate the heating and cooling demand, energy consumption, overheating risk, and carbon emissions of a home.
Embodied carbon	Embodied carbon is the carbon dioxide (CO_2) emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure.
Energy balance	The assessment of the amount of energy lost through the thermal envelope vs the amount of energy gained, with the difference made up by heating or cooling to maintain a balance.
Energy/ thermal modelling	Energy modelling of buildings is a process that uses computer software to simulate how a building will consume energy based on its design, materials, and systems.
EPD	Environmental Product Declaration, used to determine the environmental footprint of a product following life cycle assessment, verified independently.
Form factor	The ratio of total external surface area of the thermal envelope (including the floor slab area) to the conditioned floor area. Typically, a large building will have a lower form factor than a smaller one. A simpler shape will also have a lower form factor than a more complex shape. The lower the number, the less insulation needed in the same climate (everything else being equal).
Frequency of overheating	The amount of time in a year the interior spends at 25ºC or above. Note this can assume night and window ventilation, so if the building is modelled with more ventilation than used in practice it may overheat more than predicted.
fRsi	Temperature factor. Value between 0 and 1 that expresses how cold the inside surface of a junction is likely to get. The lower the number the higher the risk of mould. Numerically this is the difference between the interior surface temperature and the exterior air temperature, divided by the average temperature difference between interior and exterior.
g-value	Fraction of solar heat energy that enters a building compared to that which hits the outside of the glazing unit. Roughly equivalent to Solar Heat Gain Coefficient (SHGC) which is sometimes published instead for glazing units.
Heat loss area	The exterior area of the building that is between interior heated space and the exterior air, through which heat is lost - generally the walls, floor, roof and windows of a building. If a building is joined to another building, the adjoining area is not a heat loss area as it is attached to another heated space.
HECC	The Homestar Embodied Carbon Calculator developed by BRANZ for NZGBC, an easy to use tool for estimating the embodied carbon content of a typical home.
HPCDH	The High Performance Construction Details Handbook, a document that covers a wide range of typical thermal bridges, assemblies and build-ups used in New Zealand, produced by Passive House Institute New Zealand, BRANZ and Jason Quinn.
HVAC	Heating, ventilation, and air conditioning systems.
Hygrothermal modelling	Hygrothermal modelling uses a computer program to model the long-term effects of heat and moisture within and through parts of a building and assesses interstitial condensation risks.
Internal heat gain	The heating in a building from its occupants and the use of appliances within the thermal envelope.
kgCO²-e/m²	Kilgograms of carbon dioxide equivalent per square metre (of the home). A measurement of embodied carbon.
kWh	Kilowatt hour, a unit of energy. A 2kW portable heater on for one hour would use 2kWh (2000Wh) of energy. 1kWh = 3.6MJ (megajoules). A 1m² window in direct sunlight allows approximately 1kW of energy into the home.
kWh/m²/year (sometimes abbreviated to kWh/m²)	Kilowatt hours per m² per year. Measures the space heating demand compared with the usable or conditioned floor area (CFA in Homestar® v5, measured externally of the insulation; ICA or internal conditioned area in v4.1, measured internally of the insulation).

Life cycle assessment	Life cycle assessment (LCA) calculates the environmental footprint of a product or service over its lifecycle. LCA tools include HECC (for embodied energy only - see above), the BRANZ LCAquick tool and ETOOL LCD.
Low-e coatings	Low emissivity coating, most commonly on glass surfaces between double or triple pane windows. Low emissivity coatings reduce heat transfer by lowering the level of infrared radiation transmission. They achieve this by reflecting IR radiation and work best if there is both a physical gap and the coating is not covered with dirt or condensation (which is why they are commonly used in the sealed environment between glass panes). There are many types of low-e coatings and the thermal performance can vary significantly between them.
Mandatory minimum	Each Homestar® star band has a set of mandatory minimums that must be met. These dictate the performance levels we are aiming to achieve in each climate zone with each typology.
Mechanical ventilation with heat recovery (MVHR)	Also known as heat (or in some applications, energy) recovery ventilation or comfort ventilation. A whole-house ventilation system that exchanges heat between the exhaust air and the supply air. Fresh air is typically delivered to living areas (e.g. living room and bedrooms) and extracted from kitchens and bathrooms. MVHR units do not necessarily supply additional heat into the supplied air. However, a supply duct radiator, heat pump or electric coil can be used to add heat or coolth to the new air before or after it leaves the MVHR unit.
Negative pressure ventilation	A mechanical ventilation system that uses fans to remove the air within the building and de-pressurize it, pulling make up air into the building through trickle vents and open windows.
Positive pressure ventilation	A mechanical ventilation system that uses fans to push air into the building, pressurizing it. The air is then forced out of the building through any gap it can find. Positive pressure systems are not acceptable at any Homestar level.
psi value	Measure of heat loss ('thermal bridging') within a junction of two thermal elements, measured in W/mK. Represents the rate at which heat passes through a junction per metre per Kelvin temperature difference [W/m/K]: for example, the junction between two walls forming an external corner. The length of the junction (ie height of the corner) is multiplied by the psi value to calculate the heat loss coefficient for that corner.
R-value (m2K/W)	Thermal resistance rating used to determine a material or assembly's ability to resist heat flow.
S/V	Surface to volume ratio - an assessment of the compactness of the building form.
Service cavity	A service cavity is a secondary cavity (that may or may not be insulated) usually to the inside of the structural elements and the AVCL (air and vapour control layer). It contains the wiring, plumbing etc to keep penetrations of the AVCL to a minimum. The service cavity is usually but not necessarily insulated. Commonly, the AVCL is tested for air leakage before insulating the service cavity or installing the interior finish.
Shading factor	A measure of how much solar heat gain enters through a window compared to an unshaded window.
Structural Insulated Panel (SIP)	A panellised off-site construction building system. The panels consist of an insulating foam core sandwiched between two structural facings, typically oriented strand board (OSB). The panels are cut to size in the factory and are delivered to site.
Thermal bridge	A location in the thermal envelope where the uniform thermal resistance is changed by higher conductivity materials or geometry change.
Thermal conductivity	A material's ability to transmit heat is measured by the thermal conductivity (or lambda value). Unlike R-value, the thermal conductivity of a material remains the same irrespective of the thickness of the material.
Thermal envelope	The surfaces that enclose the building's conditioned spaces, which may or may not include garages. This includes the floor area to the exterior. For tools such as ECCHO and PHPP, external dimensions are used. This means from the bottom of the insulation below the concrete slab to the top of the insulation in the ceiling.
Thermal mass	The ability of a body of material to absorb, store and subsequently release heat (due to its specific heat capacity and its mass).
Transmission heat loss	The loss of heat energy via the building components of the house.
Upfront carbon	The carbon emitted in the production phase of products and materials, from mining and processing of natural resources, transport to processing sites, and the manufacturing phases, before any construction begins.
U-value (W/m^2K)	Thermal conductance, the inverse of thermal resistance (R-value). Describes the heat flow per m^2 of an assembly per degree Kelvin.
Ug-value	U-value at the centre of a pane of glass. Note that this is not the U-value of an entire window (Uw) which must be calculated to include the balances of losses through the glass and frame.
VLT	Visible light transmission. VLT is expressed as the percentage of light allowed through the glass.
Waffle pod	A structural slab system that is made up of concrete ribs with plastic or polystyrene pods between, and a concrete slab on top.
Warm roof	A roof build up where the insulation is on the exterior of the structure.
WRB	Water resistive barrier. This is typically the flexible wall underlay but this can be the top layer of a rigid air barrier product used under the ventilated rain-screen cladding. Used to designate the control layer in the building assembly that is intended to stop rainwater entry.