Carbon

EN2: Embodied Carbon

Embodied carbon and life cycle assessment overview

Fifteen percent of the total greenhouse gas emissions in New Zealand relates to domestic buildings, according to the [Ministry for the Environment](). Two thirds of that 15% comes from operational emissions, including on-site fossil fuel for heating and one third comes from [embodied emissions](). In Homestar v5, all projects must carry out a full [life cycle assessment]()module A-D of EN 15978. However, only upfront carbon (A1-A5) is related to the points awarded.

A typical new standalone house in New Zealand has upfront emissions of around 180kgs/m². [BRANZ research]() indicates we need to reduce this by 80% or more to meet our international obligations. There is no mandatory target to meet for the assessment result at the time this design guide was published. Instead, the aim is to provide the starting point to reduce greenhouse gas emissions associated with products and materials used to construct a home.

Although Homestar EN2 only covers embodied carbon A1-A5, a significant reduction in operational carbon will also be achieved thanks to the mandatory minimum requirements from EF4: Energy Use and EF3: Water Use. A reduction in embodied carbon is also recognised in EN3: Sustainable Materials and EN4: Construction Waste. Therefore, we have included the full life cycle assessment example in this overview before we dive deeper into embodied carbon.

Life cycle assessment diagram with all stages from A-D

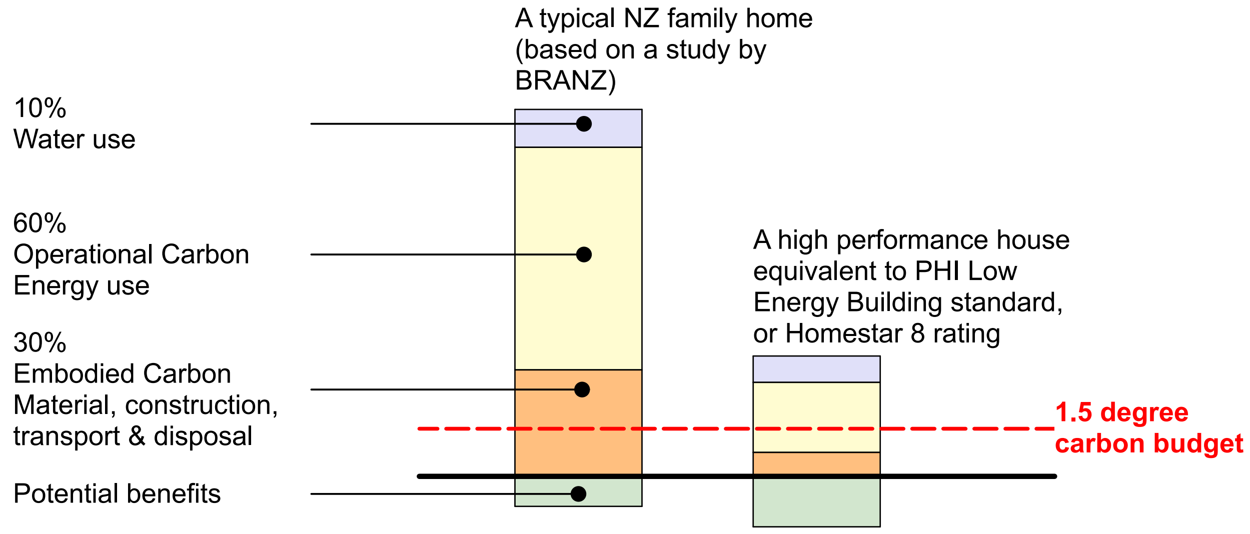
The bigger picture

Undertaking a building life cycle assessment is about having the bigger picture of the environmental impact throughout the estimated service life of 90 years (in Homestar protocol - note this can differ in other methodologies). Although Homestar EN2 only covers embodied carbon A1-A5, a significant reduction in operational carbon will also be achieved thanks to the mandatory minimum requirements from EF4: Energy Use and EF3: Water Use. A reduction in embodied carbon is also recognised in EN3:Sustainable Materials and EN4: Construction Waste. Therefore, we have included the full life cycle assessment example in this overview before we dive deeper into embodied carbon. For more information on the trajectory for housing construction emissions, see [Carbon Budget Sensitivities Analysis]()

Embodied carbon (A1-A5, B1-B5, C1-C4, D)
The product and construction stages (A1-A5) generally account for 15% of the total life cycle carbon emissions. Because most of the building materials and systems need maintenance and replacement (B1-B5) during the lifetime of a building, this roughly adds another 15%. High-performance buildings generally use more building materials up front. Therefore, it is common to see a slight increase in A1-A5 embodied carbon emission. It is important to note that biogenic carbon is excluded from the upfront emissions calculation in Homestar.

Operational carbon - Operational energy (B6)
According to the reference buildings established by BRANZ, an average detached house in New Zealand has more than 50% of the total life cycle carbon emission coming from operational energy alone during the 90 year assessment period. (BRANZ has since changed to 50 year service lifes to align with the MBIE WoLEC methodology). Depending on the climate, and according to the results of the four case studies in this guide, Homestar 6 levels of energy efficiency typically provides 10%-30% reduction in the total operational energy use. Homestar 8 typically provides 40%-60% reduction.

Operational carbon - Operational water (B7)
When it comes to operational water use, the NZ mean winter water use is 159L per person per day, and the average summer water use is 231L/p/d according to BRANZ Study report SR469 (2022). Pumping and treating potable water requires energy. Hence water consumption has a carbon content. This accounts for about 10% of a building's life cycle carbon emissions. Homestar 6 level of water efficiency generally means about 40% reduction compared to New Zealand's benchmark, while Homestar 8 can result in a reduction of over 50%.



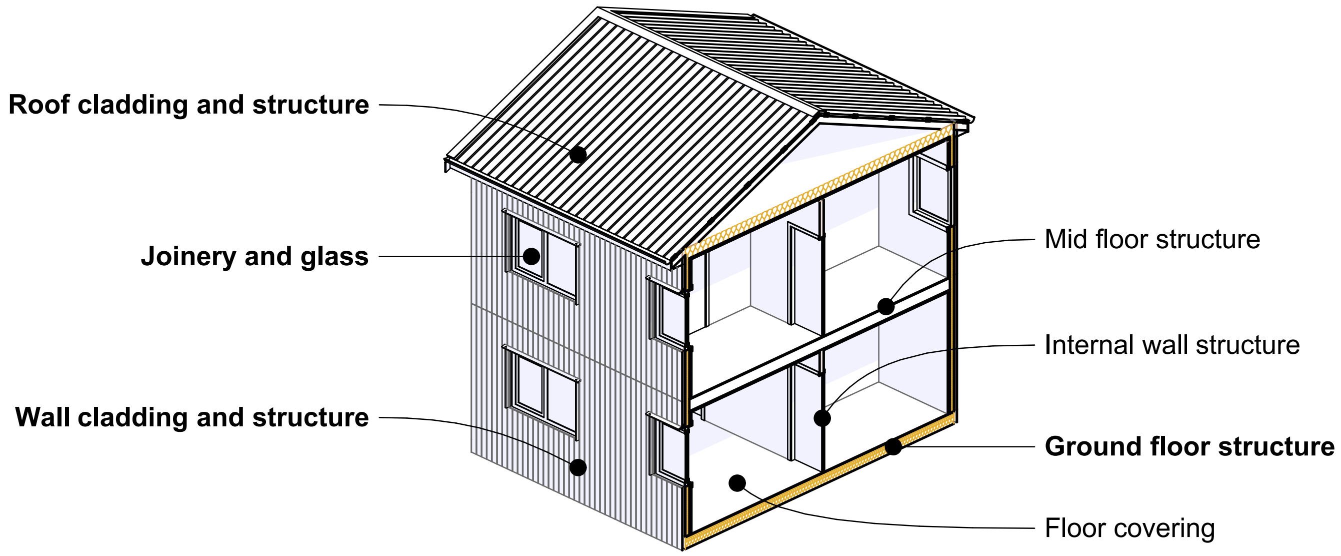
A simplified diagram of life cycle carbon emissions of a typical New Zealand house vs a small timber framed house on piles with Homestar 8 level of energy efficiency. Note this diagram is illustrative. In practice, it is difficult to achieve embodied emission reductions of this scale.

How HECC can help us reduce embodied carbon emission

HECC (Homestar Embodied Carbon Calculator) is a tool that assesses the cradle-to-cradle life cycle embodied carbon of homes with traditional constructions (e.g. timber/steel framed homes).

It is generally suitable to be used on standalone houses and multi-unit developments that use NZS3604 type construction methodologies. Apartments or specialised structural systems such as rammed earth are beyond the capability of HECC to assess with reasonable accuracy. A more comprehensive software such as LCAquick would need to be used for apartment projects.

To demonstrate the working process of using HECC to identify areas of improvements and the ways to interpret results, we have modelled the Homestar 6 version of case studies 01-03 as the baseline. Based on the results, additional effective analysis and testing in HECC is provided as worked examples.



The 'big four'

Within any project, certain elements will often end up being the largest contributors to the embodied carbon of the building. HECC has been designed to capture seven major building systems in common residential design. Among them, the four systems in **bold** are often the most impactful.

- **External wall (cladding, structure, insulation, finishes)**
- Internal wall (structure, insulation, finishes)
- **Windows (frame and glazing)**
- **Roofs (cladding, structure, insulation, finishes)**
- Mid-floors (structure, insulation)
- **Ground floor (structure, insulation)**
- Floor covering

Worked examples

The worked examples in the next three pages will take you through the carbon reduction considerations, comparison, and analysis from different angles and depths using our case study buildings.

For almost all the case studies, the embodied carbon during the use stage (B) contributes more to the building's carbon footprint than A1-A5, mainly due to the operational energy they require (or lose). Other materials are carbon intensive because of their short service life which means they may need to be replaced a number of times during the building's lifespan - for instance floor coverings such as carpet, or steel cladding in highly corrosive environments.

<u>**Case study 1 and 2 results and comparison**</u>

Case study 1 HS6
Structure: Timber frame subfloor, floor, wall, and roof
Cladding: Timber weatherboard
Roofing: Profiled metal roofing on trussed roof
Joinery: Thermally broken aluminium with low-e argon filled double glazing

Results, and potential improvements:

- Case study 1 has a very low total embodied carbon emission and a good result when it is quantified in [$kgCO_2$-e/m²].
- The main contributing factors of this is the extensive use of lightweight, renewable materials, and modest window sizing.
- With the limitations of HECC and the exclusion of biogenic carbon, we lack options to further improve the embodied carbon emission for case study 1. To achieve a better result (closer to the 1.5 degree carbon budget), a more detailed calculation on [LCAquick] or similar should be performed to, reflect specific material selection and [EPD] data etc.

Case study 2 HS6
Structure: Fully insulated concrete footing and slab, timber wall and roof
Cladding: Same as CS1
Roofing: Same as CS1
Joinery: Same as CS1

Results, and potential improvements:

- Case study 2 has a higher carbon footprint overall and per m², compared to case study one.
- The inclusion of the attached garage is the main driving factor. > Consider a carport instead?
- The concrete slab is the second most impactful difference. > Consider lower carbon concrete?
- This typology has larger window areas relative to floor area than Case study 1 and careful consideratrion of window area and orientation is required.

Comparison
These two homes are the same basic building, but with some key differences, primarily the addition of a garage, more glazing area, and a concrete slab as opposed to a suspended timber floor. The results of the two carbon models show the impacts these decisions have made:

- Total climate change impact stages A1 to A5 increased 86.35%
- Climate change impact intensity increased 44.8%

For these two dwellings you would receive 1 point for each under EN2 for doing the embodied carbon modelling.

- Case Study 1 would receive additional 2 points for being less than 132$kgCO_2$-e/m²
- Case Study 2 is over the minimum target of 156kgCO²-e/m²

Summary Sheet

Options

Concrete Carbon Content ○ lower ◉ higher

Building Gross Floor Area 102.54 m²

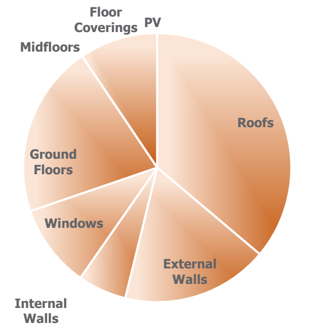
Results

Total Climate Change Impact (A1-A5) **12,832** kg CO_2 eq
Climate Change Impact Intensity **125** kg CO_2 eq/m²

Climate Change [kg CO2 eq]

	A1-A5	B	C	D	Total
Roofs	4,637	4,456	1,217	-1,823	8,487
External Walls	2,272	3,164	1,901	-522	6,816
Internal Walls	754	870	812	-90	2,346
Windows	1,289	2,623	23	-1,399	2,536
Ground Floors	2,668	400	1,620	-315	4,373
Midfloors	0	0	0	0	0
Floor Coverings	1,213	7,479	205	0	8,897
PV	0	0	0	0	0
Total	**12,832**	**18,992**	**5,778**	**- 4,149**	**33,454**

Climate Change Impact - modules A1-A5



Case Study 01 - embodied carbon results, Homestar 6 specification

Summary Sheet

Options

Concrete Carbon Content ○ lower ◉ higher

Building Gross Floor Area 131.79 m²

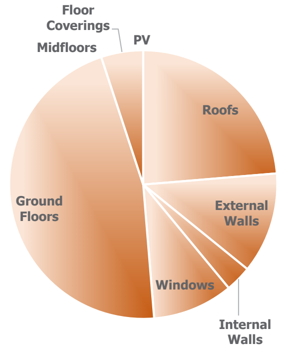
Results

Total Climate Change Impact (A1-A5) **23,913** kg CO_2 eq
Climate Change Impact Intensity **181** kg CO_2 eq/m²

Climate Change [kg CO2 eq]

	A1-A5	B	C	D	Total
Roofs	5,661	5,450	1,434	-2,244	10,301
External Walls	2,909	4,062	2,450	-673	8,749
Internal Walls	754	870	812	-90	2,346
Windows	2,321	4,547	39	-2,127	4,779
Ground Floors	11,055	522	1,218	-828	11,967
Midfloors	0	0	0	0	0
Floor Coverings	1,213	7,479	205	0	8,897
PV	0	0	0	0	0
Total	**23,913**	**22,930**	**6,158**	**- 5,962**	**47,039**

Climate Change Impact - modules A1-A5



Case Study 02 - embodied carbon results, Homestar 6 specification

Approach	Points
Full lifecycle assessment, modules A-D of EN 15978	1 point

Additional points are based on the predicted cradle-to-gate and construction stage emissions (modules A1-A5 of EN 15978). Maximum points are awarded for homes that reduce A1-A5 emissions below 60kg.CO_{2-e}/m².

Percentage increase on emissions target	Materials and construction stage (A1-A5) emissions: kg.CO_2-e/m²	Points
<160%	156	1 point
<120%	132	2 points
<80%	108	3 points
<40%	84	4 points
NZ residential carbon budget required to limit global warming to 1.5°C.	60	5 points

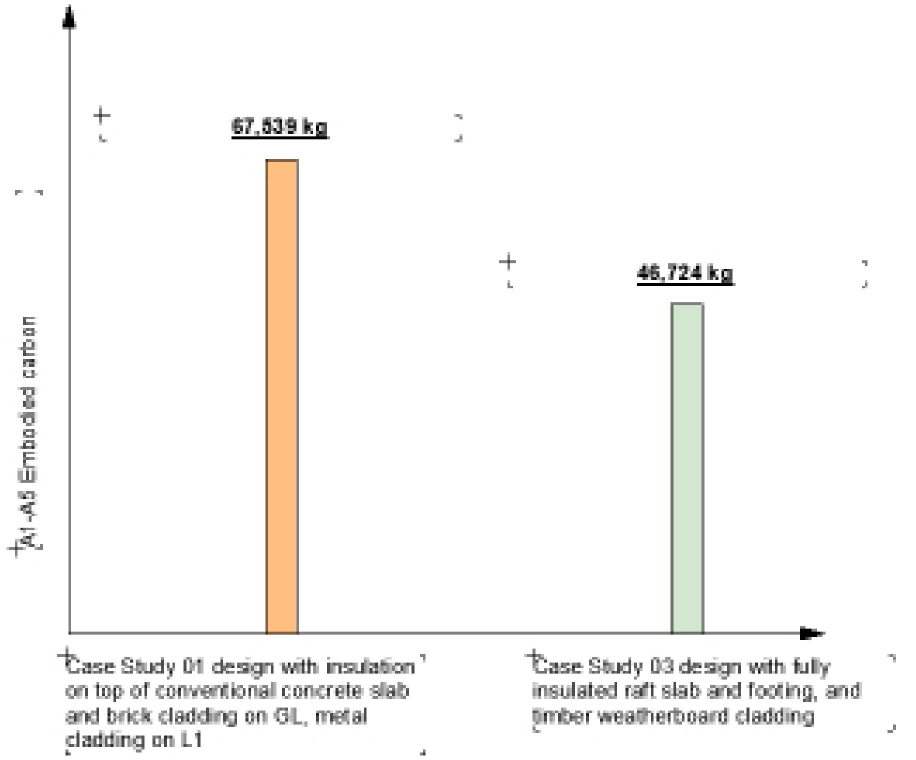
Case study 3 results and ways to improve

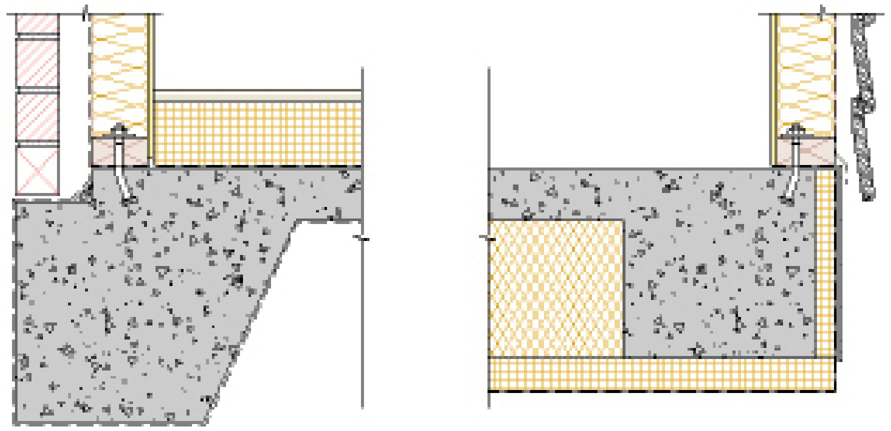
Case Study 3 current design

Structure: Insulation on top of conventional concrete slab, two storey timber wall and roof
Cladding: Brick on ground floor and profiled metal on first floor
Roofing: Profiled metal roofing on trussed roof
Joinery: Thermally broken aluminium with low-e argon filled double glazing

Results, and potential improvements:

- The external wall, including the cladding is the most dominant source of embodied carbon. > Consider a less carbon intensive cladding material
- The conventional concrete slab is the second largest source of embodied carbon. > Consider fully insulated raft slab system to reduce the use of concrete.



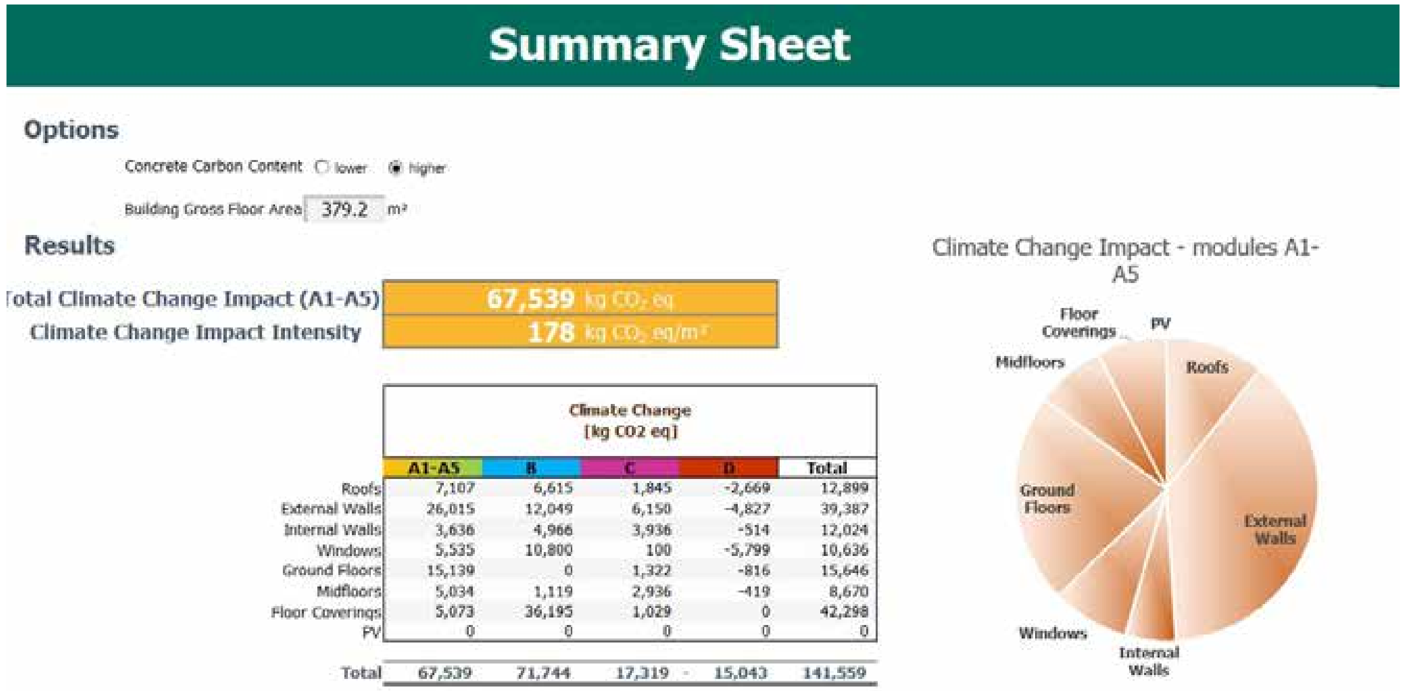


Comparison

By simply changing the wall cladding and foundation/slab systems, the results of the two carbon models show the impacts these decisions have made:

- Total climate change impact stages A1 to A5 decreased 31%

For these two versions of the same dwelling, the current design would receive 1 point under EN2 for doing the embodied carbon modelling, but only the carbon optimised design would receive any additional points - 2 points for being less than 132kgCO2-e/m²



Summary Sheet

Options

Concrete Carbon Content: lower / higher (selected: higher)

Building Gross Floor Area: 379.2 m²

Results

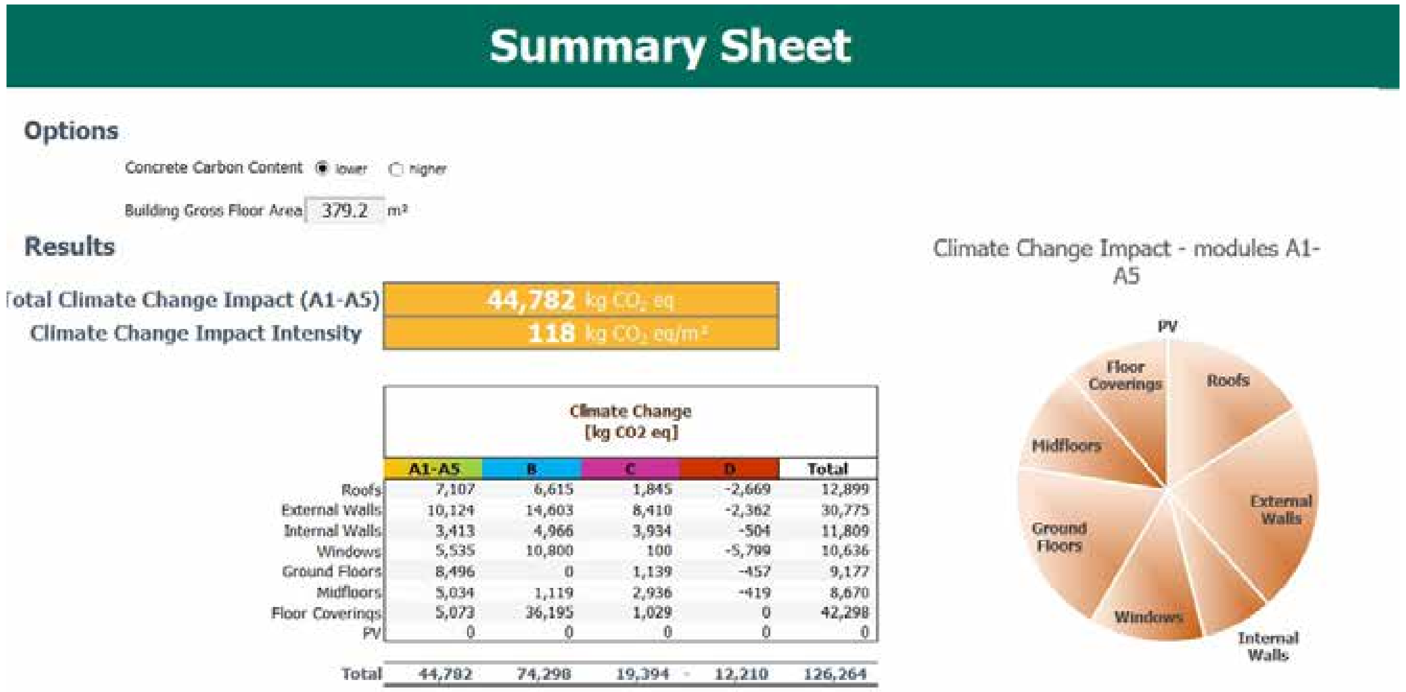
Total Climate Change Impact (A1-A5): 67,539 kg CO_2 eq

Climate Change Impact Intensity: 178 kg CO_2 eq/m²

Climate Change [kg CO2 eq]

	A1-A5	B	C	D	Total
Roofs	7,107	6,615	1,845	-2,669	12,899
External Walls	26,015	12,049	6,150	-4,827	39,387
Internal Walls	3,636	4,966	3,936	-514	12,024
Windows	5,535	10,800	100	-5,799	10,636
Ground Floors	15,139	0	1,322	-816	15,646
Midfloors	5,034	1,119	2,936	-419	8,670
Floor Coverings	5,073	36,195	1,029	0	42,298
PV	0	0	0	0	0
Total	67,539	71,744	17,319	15,043	141,559

Case Study 03 - Current design



Summary Sheet

Options

Concrete Carbon Content: lower / higher (selected: lower)

Building Gross Floor Area: 379.2 m²

Results

Total Climate Change Impact (A1-A5): 44,782 kg CO_2 eq

Climate Change Impact Intensity: 118 kg CO_2 eq/m²

Climate Change [kg CO2 eq]

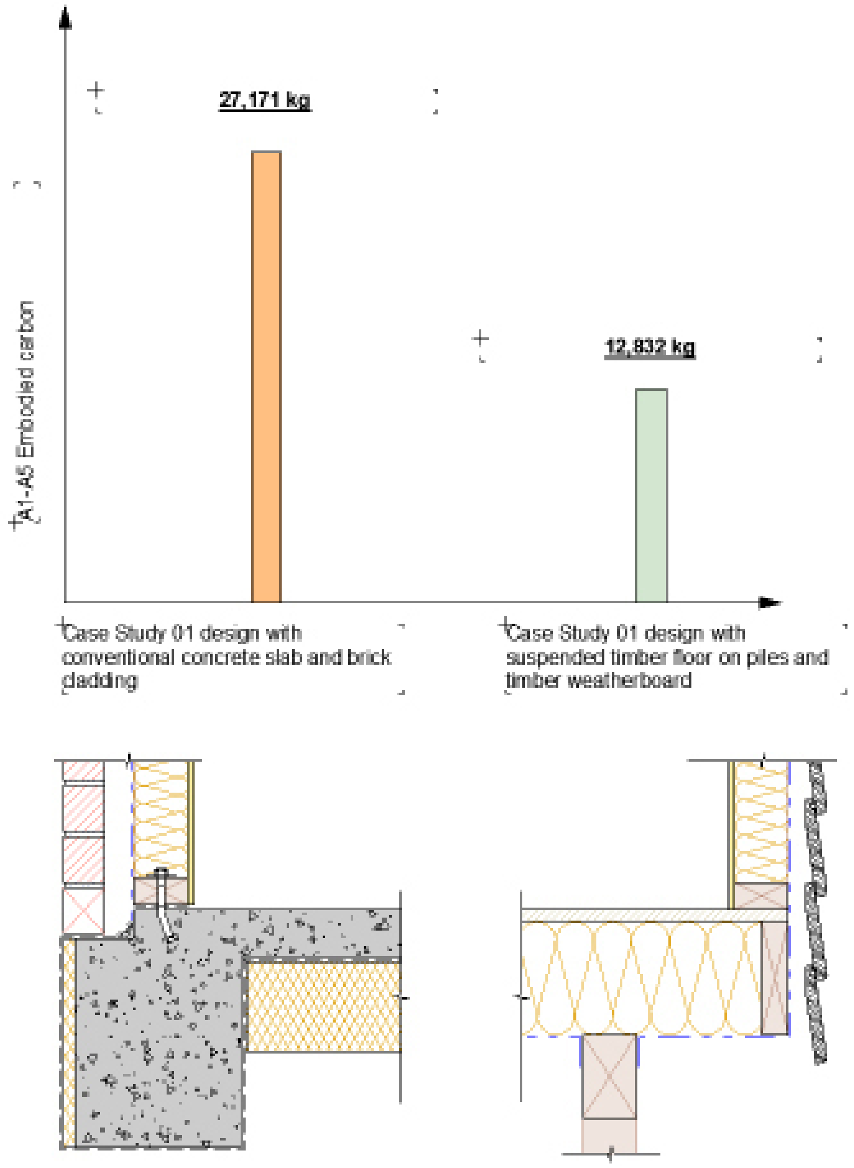
	A1-A5	B	C	D	Total
Roofs	7,107	6,615	1,845	-2,669	12,899
External Walls	10,124	14,603	8,410	-2,362	30,775
Internal Walls	3,413	4,966	3,934	-504	11,809
Windows	5,535	10,800	100	-5,799	10,636
Ground Floors	8,496	0	1,139	-457	9,177
Midfloors	5,034	1,119	2,936	-419	8,670
Floor Coverings	5,073	36,195	1,029	0	42,298
PV	0	0	0	0	0
Total	44,782	74,298	19,394	12,210	126,264

Case Study 03 - Carbon optimised design

Additional analysis based on case study 1

In the HECC model for case study 1, we tested a few big ticket items and organised a comparison table on the right, to show the impact of the different decisions. Based on these findings, we can compile different design decisions together to reduce the overall carbon impact of the project.

The diagram below demonstrates the comparison between the CS1 design with a suspended timber floor on piles and timber weatherboard cladding vs the same design with a conventional concrete slab and brick cladding. The difference in embodied carbon emission is more than double.



Additional analysis based on case study 01.

The following comparisons demonstrate the potential impact on the embodied carbon that some common design decisions can have, when assessed in HECC.

1. Case Study 1 HS6 vs HS8 according to the main spec table in the case study

HS6	HS8
12,832 kg	13,261 kg
125 kg CO_2eq / m2	129 kg CO_2eq / m2
Included option	3.2% increase in A1-A5 emissions

Note: The increase is primarily due to the increase of insulation material used. Embodied carbon of building services is not calculated in HECC.

2. Floor structure comparison

Suspended timber	Conventional (NZS3604) slab with perimeter and under slab insulation	HPCD slab with fully insulated EPS formwork	HPCD slab with 100mm XPS on top of conventional slab
2,668 kg	7,471 kg	5,826 kg	7,282 kg
Included option	37% increase	25% increase	36% increase

Note: Lower carbon concrete can be an effective way to reduce the carbon footprint for slab foundation. However, they are not available from all concrete plants. Therefore, the LCA assessment for this design guide is all based on conventional concrete.

3. Wall structure comparison

Timber frame with timber weatherboard cladding	Steel frame with timber weatherboard cladding	20 series concrete masonry wall with EIFS insulation finish
2,239 kg	3,961 kg	12,891 kg
Included option	13% increase	83% increase

4. Window type comparison

Thermally broken aluminium Low-e argon filled double glazing	uPVC frame Low-e argon filled double glazing
1,289 kg	1,310 kg
Included option	0.1% increase

5. Cladding type comparison

Timber framed wall with timber weatherboard	Timber framed wall with metal cladding	Timber framed wall with fibre cement cladding	Timber framed wall with 70mm brick vaneer
2,239 kg	4,406 kg	3,640 kg	6,818 kg
Included option	17% increase	11% increase	36% increase

On-site greenhouse gas emissions

The last carbon associated credit is the on-site greenhouse gas emissions in EF4: Energy Use. This is also the only mandatory minimum requirement related to carbon emission in Homestar v5.

Why?

Despite Homestar buildings achieving higher level of energy efficiency, where the energy comes from still matters a lot. For example, the total heating demand of a house can be fulfilled by a diesel boiler or an electric heat pump; they come with very different ongoing carbon emission. Therefore, this mandatory credit aims to aid New Zealand's energy transition goal, by encouraging efficient space heating/cooling and hot water heating devices that are powered by renewable energy.

What?

1. Fossil fuels

Although Homestar does not explicitly state fossil fuels cannot be used, it is nearly impossible to meet this mandatory criteria for all case studies when fossil fuels are used as an energy source. A typical example to avoid is using gas for cooking and hot water.

2. Heat pumps and their refrigerant

Most heat pumps provide excellent COP, which helps lowering the annual electricity demand in ECCHO. However, some refrigerants used can be a significant source of on-site greenhouse gas emissions through annual and end-of life leakage. Some older generation refrigerants have the GWP (global warming potential) of nearly 2000 times worse than natural refrigerants like CO_2.

General rule to achieve the targets

Homestar 6 space heating:

- Stick to heat pumps with R32 / HFC-32 refrigerant, which is already the most commonly used refrigerant in New Zealand.
- Avoid oversizing the heat pump where possible, to minimise the amount of power required.

Homestar 6 hot water heating:

- No attention is needed if an electric hot water cylinder or instant electric hot water heater is used.
- Follow Homestar 8 guidelines below if a hot water heat pump is used.

Homestar 8 space heating:

- Consider using low GHG refrigerants in heating, at least R32.HFC-32, but better still move to natural refrigerants such as R744 - CO2.
- Avoid oversizing the heat pump.
- Pay close attention to the weight/volume of the refrigerant charged. Larger heat pumps or ducted heat pumps tend to use a larger quantity of refrigerant, which creates higher onsite greenhouse gas emissions.

Homestar 8 hot water heating:

- Pay close attention to the type of refrigerant used. A heat pump with CO_2 refrigerant would result in lower on-site greenhouse gas emissions, but tend to be more costly.
- Pay close attention to the weight/volume of the refrigerant charged. If the refrigerant type has high GWP but there is a small amount of it, the criteria of 2 $kgCO_2$-e/m2 may still be met.

Refrigerant Leakage

Estimate leakage from refrigerants in your project here.

Add new refrigerant system

Description	Refrigerant type	Refrigerant GWP (kg.CO2e/kg)	Refrigerant charge (kg)
How water heat pump	HFC-134a	1300	0.85
Small air to air single heat pump	HFC-32	677	0.7
Large hydronic heat pump	HFC-410A	1924	5.5
CO2 Air to water heat pump	R-744	1	1.15

Maximum onsite greenhouse gas emissions ($kg.CO_2$-e/m^2) associated with space heating, hot water and refrigerants for all climate zones:

6 and 7 Homestar	8, 9 and 10 Homestar
4	2

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.