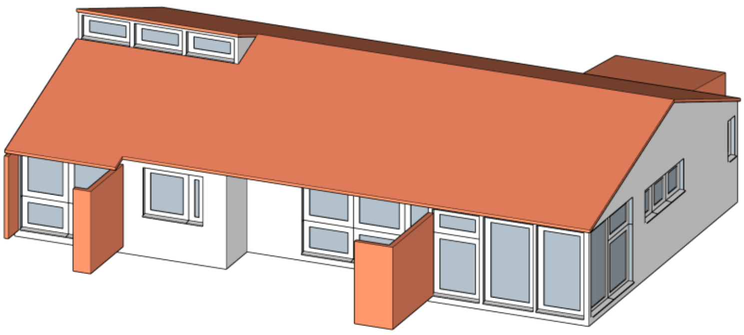
# Smithells House

# Embodied and Operational $CO_2eq$ Report



**9 April 2021**

# Purpose

We have prepared a review of embodied and operational carbon for Smithells House. We have provided six different Variants based around the existing building comparing different constructions and loads. This will provide you with the ability to directly compare between the cases and show what improvements are possible.

There was significant work developing the methodology to allow the results to match the BRANZ carbon budget work. This included discussions and reverse engineering the results from the Carbon budget paper from BRANZ and the technical paper that proceeded it. It is unfortunate but this methodology is still a work in process for NZ. We have reviewed it with folks from BRANZ and NZGBC and it is the best available at this time.

This is a schematic level review so only includes the stages through to construction (A1-A5) and operational energy (B6) and does not include any other uses (B), end of life (C) or benefits and loads beyond the system boundary (D).

This advice is specific to the named project and based on the drawings and specifications supplied by the client. The methodology is derived from [Chandrakumar 2020] carbon paper and discussions with BRANZ and is a moving target.

# Overview

The building is a timber framed building on a concrete slab. The first two variants are based on the current building built in 1976. We have then modelled four different variants with increasing levels of performance:

1. **Existing 1976 with code loads:** 90mm timber walls, a truss roof with 140mm fibreglass insulation and a concrete slab with no insulation. It uses aluminium windows and single glazing. It uses the code loads for lighting, plug loads and domestic hot water.
2. **Existing 1976 with Passive House loads:** the same constructions as the Existing 1976 with code loads variant but has Passive House loads for lighting, plug loads and domestic hot water. It also used a split unit heat pump for Heating and all in one unit for DHW (COP of 3 for both).
3. **Better Thermal Envelope:** 50mm EPS underneath concrete slab, more wall and ceiling insulation, thermally broken aluminium windows and standard double glazing. The same Passive House loads and heat pump.
4. **MVHR and uPVC double glazing:** the same construction and loads as the Better Thermal Envelope variant but with a Mechanical Ventilation system with heat recovery and uPVC windows with good double glazing.

5. **Passive House:** the same construction and loads as the Better Thermal Envelope variant but with Passive House airtightness, slightly more slab insulation and triple glazed uPVC windows.
6. **Passive House Low Carbon:** the same construction and loads as the Passive House variant but with a timber floor on piles with the equivalent performance, aluminium clad timber windows and a $CO_2$ heat pump for DHW.

Embodied and operational carbon calculation methodologies are presently being researched and developed. Operational carbon is heavily impacted by assumptions about how a house will be used and what is included or excluded from the model. Our key assumptions behind this model are outlined below.

- The heat pumps for heating and DHW in all options have a COP of 3 and the impact of refrigerant leakage has been included with R32 for heating and R134a for DHW (apart for variants 6 using $CO_2$)
- All the variants use electricity for cooking.
- The buildings operational and embodied carbon are compared over the 90-year lifespan with a minimum interior temperature of 18 degrees.
- All the results include the impact of biogenic carbon (carbon storage). FSC certified timber must be used. This does not include carbon storage of timber window frames
- The use of any onsite renewables has not been included in this report.

# Results

## Operational

The impacts of changing from the BRANZ Carbon budget / papers loads (what we call code loads) for current practice to good practice (defaults from Passive House) are significant and can be seen in the "Existing 1976 with code loads" and "Existing 1976 with Passive House loads" variants.

The significant reduction in electricity is from the BRANZ plug loads used in the carbon budget on a per quare meter basis adjusted to typical European medium efficient household (excluding cooking which was held constant).

The DHW was assumed to be direct electric resistance tank in the first variant and then heat pumps in the remaining variants. The significant reduction in DHW use is from the BRANZ DHW loads used in the carbon budget on a per quare meter basis adjusted to typical efficient system install and design. This is further reduced using a heat pump for the variants 2-6.

The reduction in heating is due to the reduction in heating demand and the use of a heat pump for variants 2-6. However the COP remained constant so the improvements from "Existing 1976 with Passive House loads" to any of the remaining variants is only due to the reduction in heating demand.

## Embodied

The embodied carbon can be better viewed in Figure 3 below. As expected, the largest impact is the removal or addition of a concrete slab. This is over 50% of the embodied energy in the total thermal envelope (including carbon storage). The embodied carbon increase as you add more EPS underneath.

The next largest impact is the additional embodied energy in the aluminium window frames or standard thermally broken aluminium frames over uPVC or timber with an aluminium cladding.

The changes from single to double and then triple glazing increases the embodied energy.

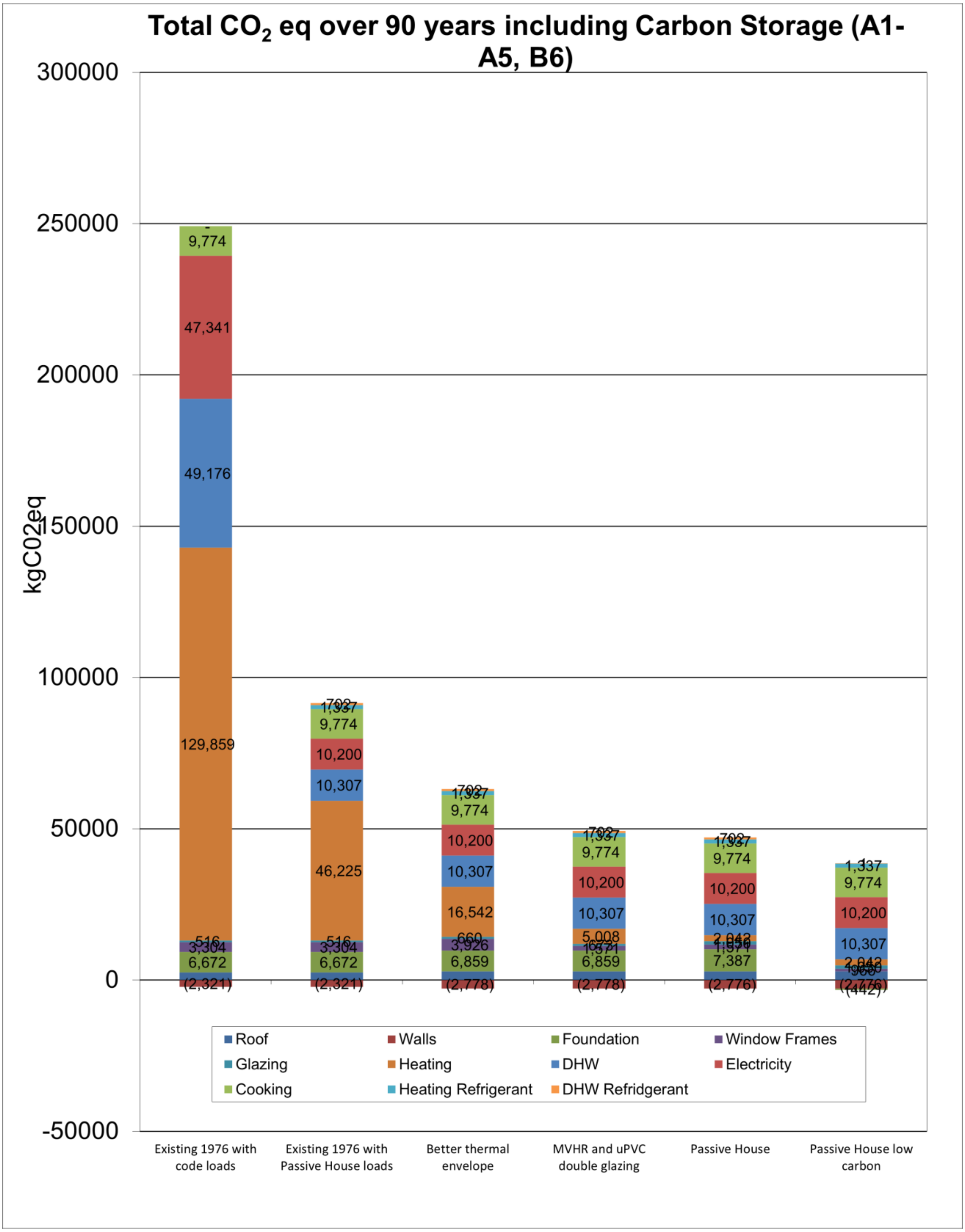



Figure 1: Total $CO_2$ eq over 90 years including Carbon Storage (A1-A5, B6)

# Recommendations

To reduce embodied and operational carbon there are several high-level design principles that can be employed. They are not necessarily enough to meet the current BRANZ target of 35,000 kg $CO_2$ eq, however they lower the operational emissions to the same level of the embodied carbon.

### OPERATIONAL

- Reduce heating demand through a higher performance thermal envelope,
  - More floor, wall, ceiling insulation
  - Better performance windows and glazing
- Use electric for heating, cooking, domestic hot water as a first step and then ideally use heat pumps for domestic hot water and heating.
- Reducing plug loads with energy efficient appliances and devices (this will require government policy changes),

### EMBODIED

- Use FSC certified timber construction to maximize carbon storage,
- Reduce construction waste,
- Minimize aluminum, steel and concrete (timber floor on piles is much lower impact),
- Timber window are the best option even if aluminum clad, then uPVC and then aluminum (solid or thermally broken) when comparing just the embodied Co2,
- The impact refrigerant has been included in this report, however currently the lowest impact options are $CO_2$ for DHW heat pump (Some options are Apricus or EcoDan) and R32 for heating and cooling. See this article for more info - [https://sustainableengineering.co.nz/weighing-the-environmental-cost-of-cooling/](https://sustainableengineering.co.nz/weighing-the-environmental-cost-of-cooling/)

### SYNERGISTIC

- Smaller less complicated buildings will reduce embodied and operational carbon,
- Using durable construction systems, think of designing for 90 years not just the code requirement of 50 years,
- Having flexible spaces that can be used by different occupants will also increase the longevity of the building,

# Operational

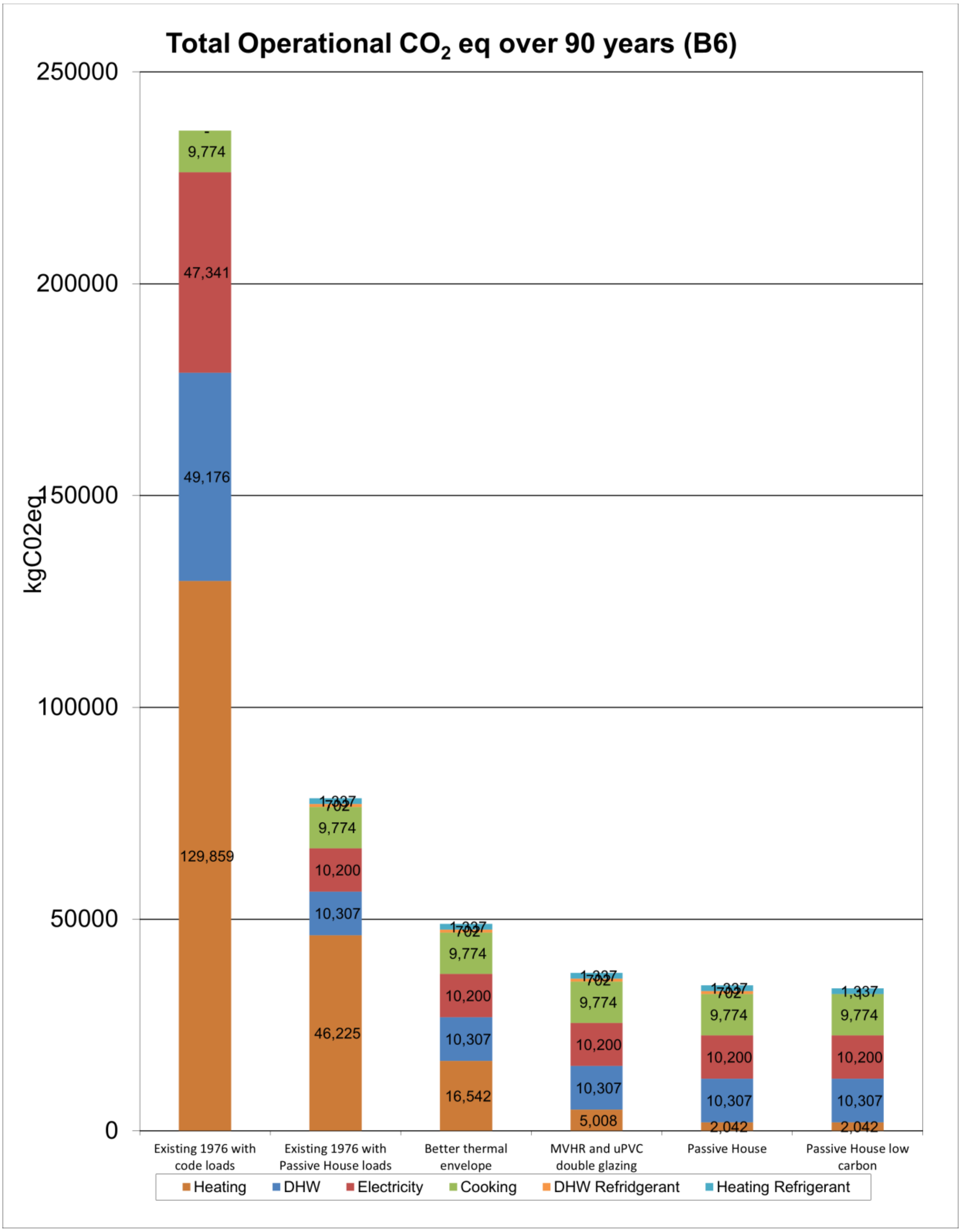



Figure 2: Total Operational CO2 eq over 90 years (B6)

# Embodied

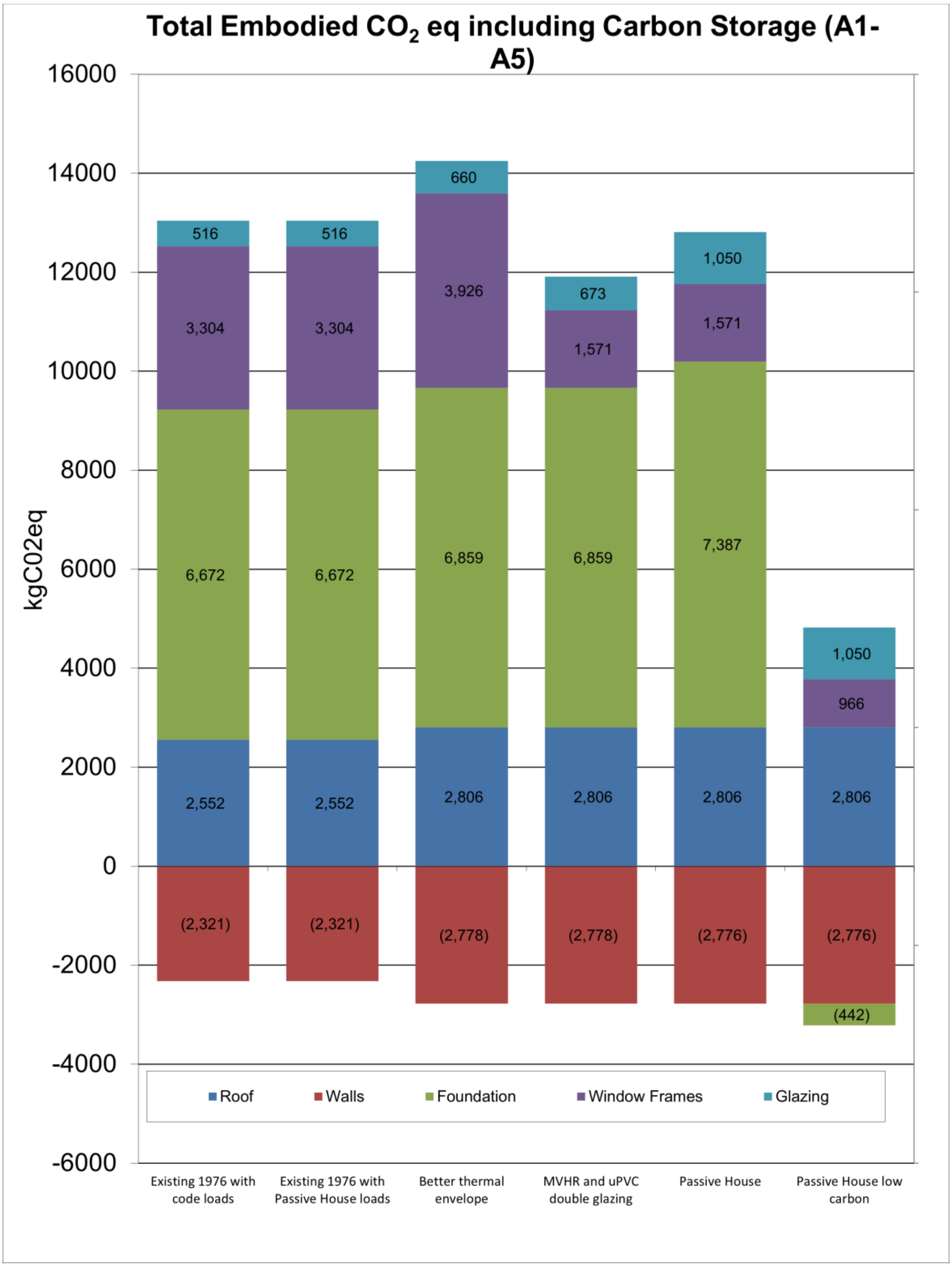



Figure 3: Total Embodied CO2 eq over 90 years including Carbon Storage (A1-A5)

# Constructions

## Wall Constructions

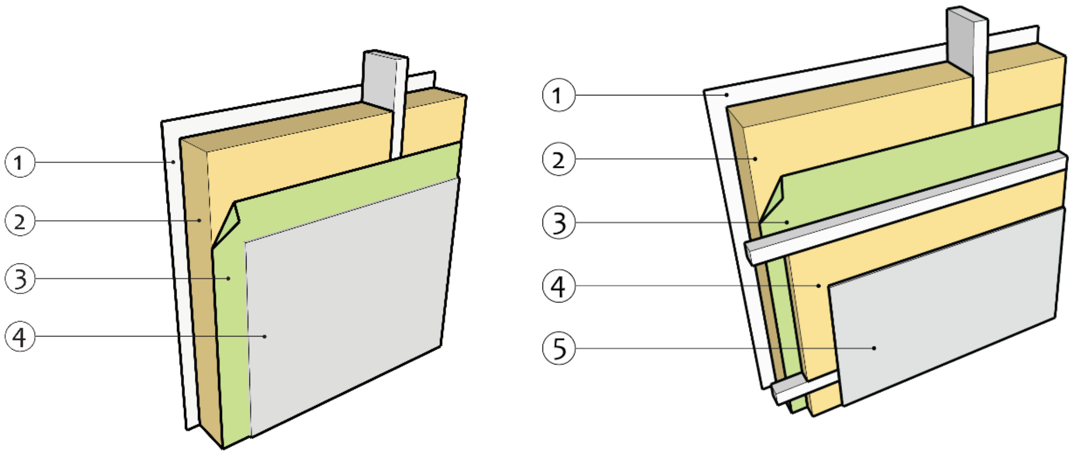



Figure 4: Conventional 90/140mm timber framed wall and timber framed wall with intello then service cavity.

Table 1: Wall Constructions Table

| *Variant* | *Name* | *Wall Construction Description* |
|---|---|---|
| *1* | Existing 1976 with code loads | [example report - details excluded] |
| *2* | Existing 1976 with Passive House loads | [example report - details excluded] |
| *3* | Better Thermal Envelope | [example report - details excluded] |
| *4* | MVHR and uPVC double glazing | [example report - details excluded] |
| *5* | Passive House | [example report - details excluded] |
| *6* | Passive House Low Carbon | [example report - details excluded] |

# Roof Constructions

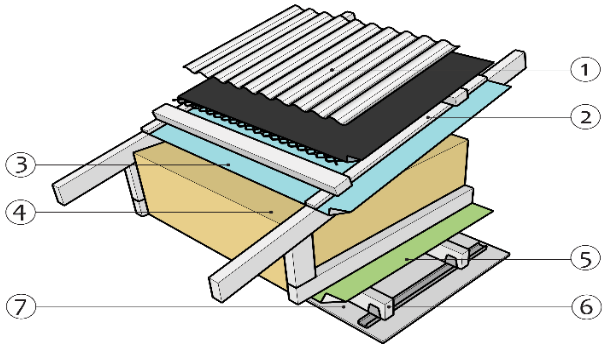



Figure 5: Roof: 1. Roofing on 2. cross-battens for ventilation over 3. Weather Resistive Barrier 2. 4. Batt Insulation, 5. Intello 6. Service Cavity, 7. Plasterboard.

Table 2: Roof table

| *Variant* | *Name* | *Roof Construction Description* |
|---|---|---|
| *1* | Existing 1976 with code loads | [example report - details excluded] |
| *2* | Existing 1976 with Passive House loads | [example report - details excluded] |
| *3* | Better Thermal Envelope | [example report - details excluded] |
| *4* | MVHR and uPVC double glazing | [example report - details excluded] |
| *5* | Passive House | [example report - details excluded] |
| *6* | Passive House Low Carbon | [example report - details excluded] |

# Slab Construction

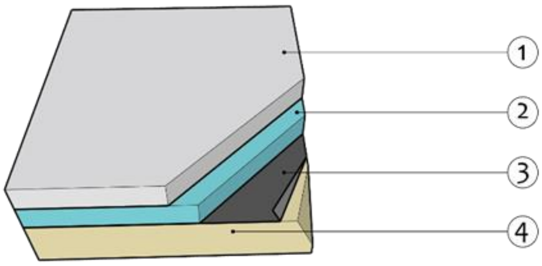



Figure 6: 1. Reinforced concrete, 2. Insulation, 3. Damp proof membrane, 4. Compacted earth.

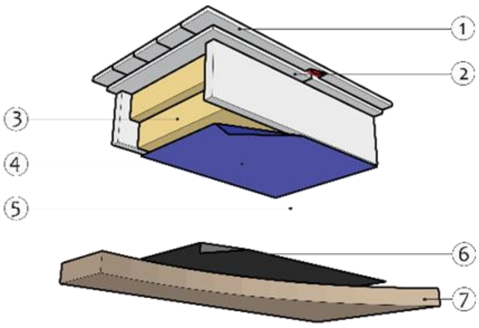



Figure 7: Suspended timber floor with insulation between joists

Table 3: Foundation table

| *Variant* | *Name* | *Roof Construction Description* |
|---|---|---|
| *1* | Existing 1976 with code loads | [example report – details excluded] |
| *2* | Existing 1976 with Passive House loads | [example report – details excluded] |
| *3* | Better Thermal Envelope | [example report – details excluded] |
| *4* | MVHR and uPVC double glazing | [example report – details excluded] |
| *5* | Passive House | [example report – details excluded] |
| *6* | Passive House Low Carbon | [example report – details excluded] |

# Assumptions and Background information

## Why LCA and what does it do?

LCA is an environmental systems analysis and accounting tool for quantifying the inputs and outputs of an option, whether a product, service or organisation and relating these to potential environmental impacts. LCA is a systematic approach, where the system of interest comprises the operations that collectively produce the product or service being investigated. The system being assessed is linked to other industrial systems supplying and transporting inputs and carrying away outputs (Figure 4), all of which is considered within the assessment.

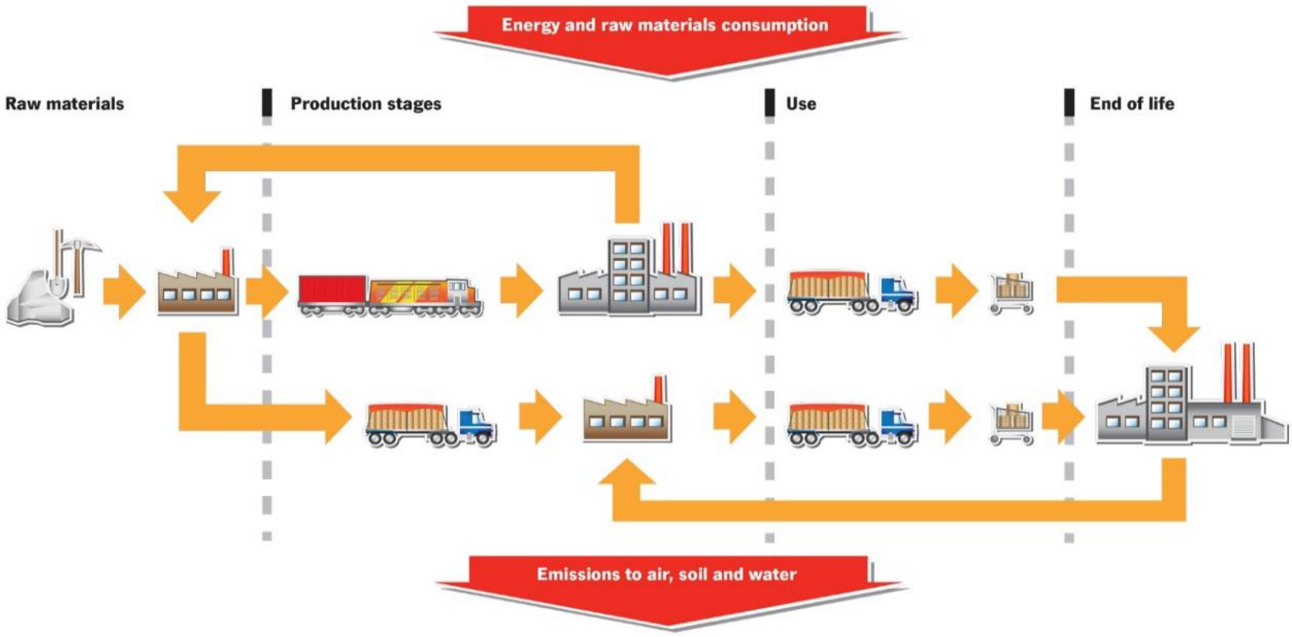



Figure 8: Example of a product life cycle.

An LCA offers a clear and comprehensive picture of the flows of energy and materials through a system and gives a holistic and objective basis for comparisons. Results are presented in terms of the system function so that the value of the function can be balanced against the environmental effects with which it is associated.

The results of an LCA quantify the potential environmental impacts of a product or service over the life cycle, to help identify opportunities for improvement and to indicate more environmentally preferable options, for example, through comparison of alternative building designs.

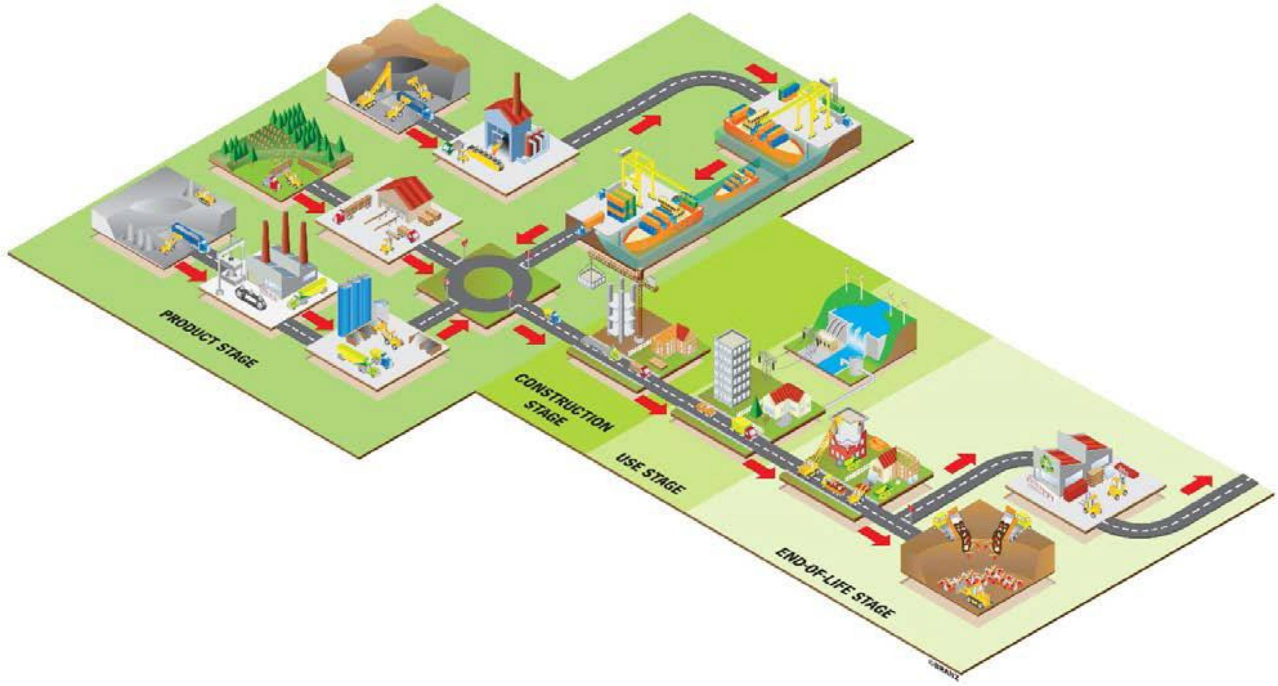



Figure 9: Depiction of a building life cycle. EN 15643-2 (CEN, 2011a) divides these four stages into discrete, numbered modules that contribute to each stage plus a 'beyond the system': Product stage (modules A1 to A3), Construction process stage (modules A4 and

# Scope of Study

This is a schematic level review so only includes the stages through to construction (A1-A5) and operational energy (B6) and does not include any other uses (B), end of life (C) or benefits and loads beyond the system boundary (D).

| Module | A1-A3 | | | A4-A5 | | B1-B7 | | | | | | | C1-C4 | | | | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life cycle stages | Product stage | | | Construction process stage | | Use stage | | | | | | | End-of-life stage | | | | Benefits and loads beyond the system boundary stage |
| Processes | Raw material supply | Transport | Manufacturing | Transport | Construction - installation proces | Use | Maintenance | Repair | Replacement | Refurbishment | Operational energy use | Operational water use | Deconstruction/ demolition | Transport | Waste processing | Disposal | Reuse, recovery, and recycling potential |
| | A1 | A2 | A3 | A4 | A5 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | C1 | C2 | C3 | C4 | D |

Figure 10: Life cycle stages as defined in the European standard EN 15978:2011 from "Introduction to LCA of Buildings", Danish Transport and Construction Agency, 2016.

# NZ electrical grid

The environmental impact of the New Zealand grid is an important component of calculating the operational $CO_2$ eq. We have used data from BRANZ for New Zealand Grid environmental impacts 2018-2050. This has a range of scenarios and we selected Mixed Renewables and extrapolated the last 5 years of data (2046-2050) until 2111 to get a grid impact (kg $CO_2$ eq / kWh) over 90 years from 2021. The values we've use for LPG, Natural Gas and Wood are from the NZ Green Building council.

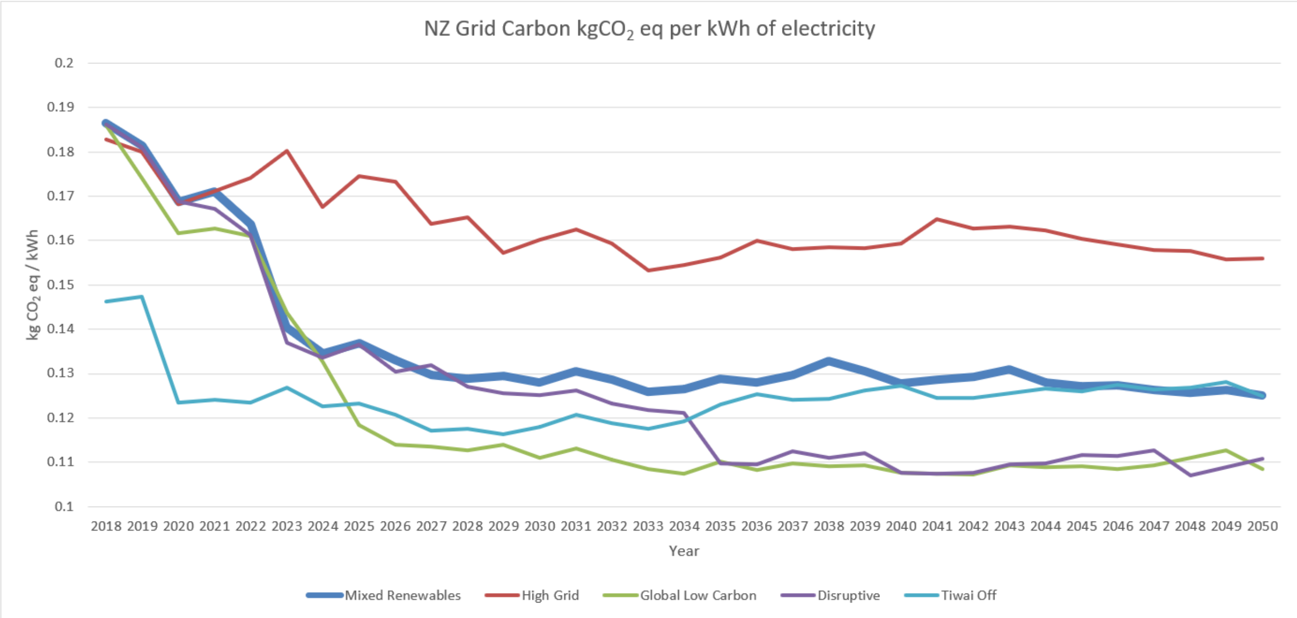



Figure 11: NZ Grid Carbon

# Internal Minimum Temperature

There is no defined standard in New Zealand for minimum temperature for analysis of operational energy usage. Using the Passive House value of 20 degrees does not a realistic estimate peoples energy use in non-Passive Houses as an average occupant won't maintain this temperature. We've used 18 degrees as an internal minimum temperature in this report as this maintains consistency with carbon paper [Chandrakumar 2020]. This means the heating demand is significantly lower when calculated at 20C.